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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

# Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

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# Measurement Techniques

*A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR*

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# DECISIONS OF THE JULY PLENUM OF THE CENTRAL COMMITTEE OF THE COMMUNIST PARTY OF THE SOVIET UNION AND PROBLEMS OF WORKERS IN MEASUREMENT TECHNIQUES

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 1-2 ,
July, 1960

By successfully bringing to life the historic decisions of the Twentieth and Twenty-first Congresses of the Communist Party of the Soviet Union under the leadership of the Communist Party, the Soviet people have attained great success in creating in our country the material and technical basis of communism. The decree of the July Plenum of the Central Committee of the Communist Party of the Soviet Union regarding the course of fulfillment of the resolutions of the Twenty-first Congress as regards the growth of industry and transportation and the introduction of the latest attainments of science and technique is of vast importance.

Acceleration of the tempo of technical progress in all branches of the national economy, especially after the June Plenum of the Central Committee of the Communist Party of the Soviet Union (1959), attained as a result of subsequent implementation of technical improvement of production, remains the most important result of work in fulfillment of the resolution of the Twenty-first. The attainments of Soviet science and technique in the investigation of a complex area, the peaceful utilization of atomic energy, rocket building, radioelectronics, and other areas of knowledge have enabled the Soviet Union to occupy a leading place in world science.

The July Plenum set important tasks in the development of the national economy and its technical progress with the use of the latest attainments of science and technique.

By its decision, the Plenum provided for the development of measures for the acceleration of the introduction of the attainments of science and technique into production, the creation and utilization of more improved machines, equipment, and instruments for the complex mechanization and automation of the productive processes, the rapid replacement of obsolescent production by new production meeting current requirements.

The Plenum pointed out that the rapid growth of machine tool building, the expansion of production and elevation of the technical level of machines, of means in mechanization and automation and other equipment have a decisive importance for the acceleration of the tempo of technical progress and opportune introduction of new productive capacities.

The Plenum suggested that the State Committee of the Council of Ministers of the USSR on Automation and Machine Tool Building, the State Planning Commission and the Committee of Standards, Weights, and Measuring Instruments of the Council of Ministers of the USSR develop measures for the introduction of a reasonably dimensioned series of equipment, instruments, and mechanisms for all branches of machine tool building, and for the standardization, unification, and typing of machine tool building production, and submit proposals on these problems to the Council of Ministers.

The Plenum recommended that there be an annual definition of the nomenclature and specifications in automata and control-measurement instruments, necessary for the completion of work on the mechanization and automation of control operations, by providing in the annual national economic plans for the production of this equipment in the necessary quantity.

The Plenum turned its attention to the need to raise the efficiency of the work in scientific research and planning institutes, design offices, of shortening the periods for the completion of scientific research and design work, and their introduction into production. They also looked into strengthening of the coordination of their activities, the liquidation of unnecessary parallelism and the narrowly departmental approach to the matter. It was proposed not to allow less essential themes to be added in the plan; to strengthen the research, planning, design and experimental base; to put in order the arrangement of technical information, and to adopt measures for the complete liberation of experimental establishments, plants, and enterprises from the production of serial products.

Great attention was given in the resolutions of the July Plenum to raising the level of economic work and increasing the struggle for improvement of the quality indices in all sections of industry and transportation.

It was proposed that the Committee of Standards, Weights and Measuring Instruments along with the Councils of Ministers of the Republics of the Union develop and present on November 1, 1960 proposals to the Council of Ministers for improvement of standardization in the national economy, having in view elevation of the role of standards and technical specifications in raising the quality of products made.

The Plenum emphasized that solving the basic problem of the current Seven-Year Plan, making maximum use of time in the peaceful economic competition of socialism with capitalism, can only be done by universally raising the tempo of technical progress on the basis of increase in the productivity of labor. To successfully solve this problem, it is necessary to bring into effect all the reserves and possibilities which our national economy has at its disposal. They consist primarily in accelerating the introduction of the attainments of science and technique into all branches of the national economy, further electrification of the country, the introduction of specialization and cooperation of enterprises and the universal application of efficient methods of work and production.

The resolutions of the July Plenum have first-order importance for workers in measurement techniques, and set important tasks which face the workers in scientific research, metrological and branch instrument producing institutes, design offices, instrument producing factories, factory measurement laboratories, and in organs of state and departmental supervision of the condition of measuring technique in all sections of the national economy.

The correct and rapid solution of problems in the development of new methods of measurement, and on that basis, questions, of the working out of efficient designs for measuring instrument improvement in the production and exploitation of instruments and the extensive introduction of automatic means of control, must be an important contribution to the matter of growth of the national economy of our country.

The automation of productive processes and of machine tool building requires the broad development in automation of control of parts in the process of producing them. This becomes the basic direction of the growth of technical measurements in machine tool building. Manual inspection of finished parts of large-scale production should be replaced by automatic inspection, characterized by high productivity, objectivity, and accuracy. The task of introducing instruments for the active control of dimensions in machine tool building into technological lines is of special importance.

The introduction of new and advanced techniques is unthinkable without modern precise measuring instruments and the latest methods of measurement. The assurance of uniformity, accuracy, and the proper use of weights and measuring instruments is a necessary condition for the organization of modern industrial production in all branches of the national economy.

In developing the decisions of the July Plenum, still more attention must be given to problems in the designing, making, and testing of models of new machines, equipment, and instruments for their transfer into serial production.

The main task of the State testing measuring instruments is the establishment of the relationship of the instruments to the rising requirements of the national economy, and the present level of domestic and foreign measuring instruments should be replaced with modern instruments based on new methods of measurement, using modern attainments of science and technique.

Considering the great attention which has been given to the resolutions of the July Plenum to design offices in the matter of creating new progressive techniques in all stages of development, from laboratory research to introduction into production, it is necessary to strengthen, still more, every-day aid by design offices to scientific research metrological institutes of the system of the Committee in order to assure the development of new highly-accurate models of measuring instruments and their transfer to industrial production.

The scientific research metrological institutes face responsible tasks in the matter of raising the precision of calibrating instruments, the development and introduction into the national economy of methods of accurate measurement, so necessary in the era of atomic energetics, radioelectronics, and the mastery of cosmic space.

Workers in measuring technique and precise machine tool construction will make their contribution to the fulfillment of the great tasks set by the historic decisions of the Twentieth and Twenty-first Congresses of the Party and the July Plenum of the Central Committee of the Communist Party of the Soviet Union.

# THIRD SESSION OF THE INTERNATIONAL COMMITTEE OF LEGISLATIVE METROLOGY

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 3-5, July, 1960

On April 4-9, 1960 the alternate third session of the International Committee of Legislative Metrology was held in Paris. In accordance with the convention, which founded the International Organization of Legislative Metrology, these sessions are conducted every two years. The preceding two sessions of the Committee were held in 1956 and 1958.

Of the 28 members of the Committee who represent countries which are members of the organization, 19 took part in the session.

The basic problems discussed at the session were :

1) General questions of organization: membership in the Organization, admissions and ratifications, the prospects of new admissions, the legislative position of the Organization in France; 2) The balance of control and planning of the budget: financial position, material status, personnel, review of the budget plan for 1961-62; 3) Relationships with other international organizations (OON, UNESCO, the International Committee of Standards and Measurements, the International Organization Electrotechnical Commission, the International Commission on Radiation); 4) Office operations: the creation of a documentation center, initial review of the plan for the location of the legislative metrology service; 5) The issuance of an organ of communication, "The International Bulletin of Legislative Metrology"; 6) The operations of member-states: a list of technical problems which is suggested for study, methods of operation of the reporting secretariats, the state of work in process (reports of the reporting secretariats); 7) The setting of the place and dates of future conferences: the International Committee of Legislative Metrology and the Second General Conference of Legislative Metrology.

The chairman of the session was the president of the International Committee of Legislative Metrology, Jacob, the director of the Belgian metrology service.

The first question, additionally included in the agenda of the day, was a review of the composition of the Council of the Presidium of the International Committee. The Committee decided that the Council of the Presidium will hencefore consist of five permanent members (instead of four), and in addition to members of the Council from the USSR, Germany, France and Switzerland, one more was elected, P. Hunt (Hungary) and one temporary member, I. Stull-Getz (Austria), representing the country in which the next General Conference will be held (1962, Vienna).

Members of the International Committee were informed that three governments had recently joined the Organization as member countries, Italy, Austria, and Guinea, and likewise of New Zealand, which had entered the Organization as a corresponding member.

In connection to these questions, the Soviet delegation, supporting the Polish delegation, drew the attention of the International Committee to the abnormal situation created due to the fact that the German Democratic Republic, which in 1956 applied through diplomatic channels for admission to the convention, has not yet been recognized as a full member of the Organization.

According to a communication of the president of the Committee the representatives of both West and East Germany were invited to the present session. However, delay in obtaining a visa for the East German representative made it impossible for him to participate in the session, regarding which a telegram was received from Professor I.Shtanek, president of the German Bureau of Weights and Measures.

The International Organization of Legislative Metrology (IOLM), with a permanent location in France, has not yet received an official charter regarding its juridical position from the government of France, although in a conference subscribed to by the French government it was pointed out that the Organization makes use of privileges and exemptions usually allowed to intergovernmental organizations.

The Committee requested its president and the director of the International office to ask the government of France to expedite review of the matter of the IOLM charter.

After reviewing the financial report for the period from October 1, 1956 to December 31, 1959, the Committee became acquainted with the position of the International Bureau of Legislative Metrology regarding personnel.

At the present time, the state of the International Bureau consists of a director who also holds another position, an assistant director (probationary), a secretary, and a clerk. The Committee approved the suggestion of the Council of the Presidium that Director of the Bureau Kostaman leave the French measuring instrument service and transfer completely to work as the director of the bureau.

In addition, assistant director Yasnorzhevskii was confirmed as a permanent employee of the bureau. Yasnorzhevskii is a metrological specialist who worked for many years in the Central Bureau of Standards of the Polish Peoples' Republic. In 1959 he was employed by the Council of the Presidium of the Organization as an assistant director of the International Bureau of Legislative Metrology for a trial period of one year.

The Committee reviewed and approved the budget of the Organization for 1960-62.

Those participating in the session then became acquainted with the question of the relationships of the International Organization of Legislative Metrology with other international organizations.

An agreement has been signed with UNESCO regarding mutual recognition and participation in work in which both international organizations are interested. The activity of the IOLM should always initiate from the resolutions and recommendations of the International Organization of Standards and Weights and the ISO. Constant close connections are therefore established between the IOLM and these two international organizations. The session also reviewed relationships with the Permanent Committee of IMEKO, which is permanently located in Budapest. This international organization, which has conducted conferences, congresses, and exhibitions on methods of measurement and measuring instruments, can by the nature of its activity, present valuable material for the IOLM. The committee recognized that it is worthwhile to have constant contact with IMEKO and to send representatives to its meetings.

The International Bureau of Legislative Metrology has begun the creation of a documentation center in which legislative documents on questions of standards and measuring instruments of all countries will be collected. In this connection the Bureau has requested all members of the International Committee to send national documentation on questions of legislative metrology and also to give information about periodicals and special works on the problems of applied metrology.

The International Bureau has set up a plan for information on the creation of a legislative metrological service, limited to ordinary controls, for those countries which have not yet implemented effective control of standards and measuring instruments. The plan contains directions on problems of legislation, rules, administration, and technical equipment. Although this document has not yet been completed, it has been sent to several countries, in particular to Venezuela, Guatemala, Iran, and India.

The Committee became acquainted with the appearance of the first edition of "The International Bulletin on Legislative Metrology," which the International Bureau proposes to issue as an organ of communication between the state-members of IOLM.

The Committee decided to issue this bulletin under the name, "Bulletin of the International Organization on Legislative Metrology," with a printing of not more than 200 copies.

The session devoted considerable attention to the work of the state-members on the supervision of secretariat-reporters or participation in them as associates.

Until now there have been 46 secretariat-reporters on various problems of measurements and measuring instruments. Of these, the USSR has five:

1. Various classes of precision of measuring instruments (VNIIM - D.I. Mendeleev All-Union Scientific Research Institute of Metrology).

2. Manometers (VNIIK - All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments).

3. Optical pyrometers (KhGIMIP - Khar'kov State Institute of Measures and Measuring Instruments).

4. Household electronic counters (VNIIK).

5. Industrial electronic counters (VNIIK).

The USSR leads other countries as a member-associate in 22 secretariat-reporter groups.

The Committee reviewed a number of questions on which it was necessary to create new secretariat-reporters. A resolution was adopted to commission the conducting of new secretariats by the following countries:

Austria - quadrants and dynamometers of great load capacity.

Belgium - the labelling and marking of tested instruments.

Spain - standard wattmeters and counters.

Spain - the measurement of petroleum products under pressure in the liquid and gaseous state.

France - the determination of industrial volumes.

Hungary - tape and wire measures of length.

Poland - instruments for the measurement of skins and hides.

As a result of applications made by a number of countries the Committee decided to introduce certain changes in the conduct of the secretariats. Thus, the secretariat on electrocounters, which the USSR had been charged to conduct along with France and Switzerland, remained only with the USSR and France. The secretariat on a dictionary of legislative metrology was transferred from Switzerland to Poland, and the secretariat on densimeters and alcoholometers was retained by Switzerland alone without the participation of Poland.

A number of countries expressed their wish to participate in the work of some of the secretariats as associates.

The representatives of countries which are the leading reporting secretariats informed the Committee of their progress in completing the work assigned to them. The Soviet representative reported on the work of five secretariats which the metrological institutes of the USSR conduct. At the present time plans have already been set up on international recommendations on manometers, electrocounters and on classes of accuracy of measuring instruments distributed by the associate countries for reference. The project of recommendations on optical pyrometers also has been prepared, but for the present coincides with competent organizations within the USSR. A report was also made of the participation of the USSR as an member-associate in the work of several secretariats conducted by other countries.

The director of the bureau gave the members of the Committee, for their information, the plans of several recommendations, among them the plan of recommendation on various categories of precision of measuring instruments, as set up by the D.I. Mendeleev All-Union Scientific Research Institute of Metrology.

The president of the Committee reported on a conference held by six secretariats in May, 1960, at Braunschweig (West Germany) on problems of weighing. The purpose of this conference was to review the prepared plans, exchange opinions and establish a single policy regarding instruments for measuring weight.

The Committee decided that for the purpose of agreement of the work of the bureau, announcements will be made of all conferences of working groups of the secretariat-reporters, and that in the case of large conferences in which many countries will participate, invitations to them will be sent out by the president.

The Committee adopted a resolution on the conduct of the next session and the General Conference on Legislative Metrology in Vienna in May-June, 1962.

The Third Session of the International Committee of Legislative Metrology has shown that the International Organization created at the end of 1956 has proceeded to concrete work on various problems of applied metrology. National metrological organizations, fulfilling the duties of reporting secretariats, have already set up a number of plans of recommendations on measuring instruments which present considerable interest. The operations of the working organ of the organization, the International Bureau of Legislative Metrology, are being developed successfully; it has created a documentation center, worked out a plan for a typical legislative metrological service, prepared the systematic issuance of "The International Bulletin of Legislative Metrology," and is organizing the work of reporting secretariats.

# THE FORTY-EIGHTH SESSION OF THE INTERNATIONAL COMMITTEE OF WEIGHTS AND MEASURES

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 5-6,
July, 1960

On May 10-11, 1960, the 48th alternate session of the International Committee of Weights and Measures was held in Sèvres in the International Bureau of Weights and Measures. The session was called by the president of the International Committee in connection with preparations for the Eleventh General Conference on Measures and Weights, scheduled for October, 1960.

The following were presented to participants in the session as basic questions: the composition of the Consultative Committee on standards for the measurement of ionizing radiation, a review of the first report of the Consultative Committee, a new review of the plan for the metrical convention, and steps taken in preparation for the Eleventh General Conference on Weights and Measures.

Of 18 members forming the International Committee of Weights and Measures, 12 took part in the session.

In 1958 the International Committee of Weights and Measures adopted a resolution regarding the creation of a Consultative Committee on standards for the measurement of ionizing radiation. In April, 1959 the first session of the Consultative Committee was held, and as a result of it a report was prepared which defined the task of the Consultative Committee and a program of work of the International Bureau of Weights and Measures in connection with the distribution of its activity in the area of radioactivity and ionizing radiation.

The Consultative Committee gives two recommendations in its report. In the first of these, it is noted that the International Bureau of Weights and Measures should be a central organization in the defining of quantities and units and in the establishment of standards in the measurement of radioactivity and ionizing radiation, including neutrons. In the second recommendation, the necessity is pointed out of agreement of the work program of the International Bureau of Weights and Measures in the area of ionizing radiation with the activity of the International Agency on Atomic Energy.

In accordance with the recommendations of the Consultative Committee the president of the International Bureau of Weights and Measures carried out, at the beginning of 1960, the transfer of the international standard of radium from the Radium Institute in Paris to the depository of the International Bureau at Sèvres.

The International Committee approved the report and set the composition of the Consultative Committee, in which, upon the suggestion of several members of the Committee, new scientific organizations working in the area of ionizing radiation were included. At the suggestion of the Soviet representative in the Consultative Committee, the All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements was introduced as a member in addition to the D.I. Mendeleev All-Union Scientific Research Institute of Metrology.

In connection with the need to create in the International Bureau a new section on standards for the measurement of ionizing radiation, a building is being planned for a laboratory with three sections: 1) for dosimetry of x- and gamma-rays; 2) for absolute measurement of activity; 3) for the measurement of streams of neutrons. The participants in the session were then acquainted with the plan of the laboratory building.

The new area of work of the International Bureau requires the attraction of scientific associates into its staff. The International Bureau requested participants in the session to send specialists in ionizing radiation for work in the bureau.

Then the participants in the session proceeded to a discussion of the point on the agenda for the day, entitled "New Review of the Plan for the Convention."

The question of the need to review the metric conventions of 1875/1921 was submitted to the Tenth General Conference on Weights and Measures in 1948. The Conference approved a resolution to conduct an inquiry of the member-nations regarding desirable amendments and supplements to the existing conventions.

The Tenth General Conference was informed in 1954 of the results of the inquiry and commissioned the International Committee on Weights and Measures to continue the study of these materials. In connection with this, the International Committee organized a commission to review the metric conventions.

At the 47th session of the International Committee of Weights and Measures, a report was presented by the commission gathered together at the convention in April, 1958. The commission presented two plans. In one of them only an insignificant amendment to the conventions was proposed; in the second, a basic alteration of the convention. A majority of the members of the Committee spoke in favor of the first plan.

The plan of the convention reviewed by the International Committee was corrected by the commission and sent in this form to the director of the International Bureau of Weights and Measures by all members of the International Committee for decision.

After receiving comments upon the plan, the director of the International Bureau composed a new, slightly changed text of the convention and sent it in March, 1960 to the members of the International Committee, and a also through diplomatic channels to the governments of all the countries subscribing to the metric convention. In the preface to "The first plan of changes in the metric convention," it is pointed out that amendments to the plan must be presented to the International Committee before June 1, 1960, after which time there will be a second plan which will serve as the basis for decisions at the Eleventh General Conference on Weights and Measures.

From the Soviet viewpoint, an important addition was made to the indicated plan, consisting of the provision that, for the purpose of strengthening the authority of the International Organization on Weights and Measures and to assure more effective representation of member-governments in the International Committee on Weights and Measures, the latter should not be selected on a personal basis but should consist of representatives of the governments of countries elected to the staff of the International Committee.

The Soviet proposal was discussed in detail at a session of the International Committee held May 10-11 of this year. Because the members of the International Committee considered it necessary, for the given question, to know the opinion of their governments, a resolution was adopted to transfer it to the review of the governments of all the member-countries of the metric convention as material supplementing that sent out in March, 1960, "The first plan of changes in the metric convention," in order that discussion of this question might be resumed at the October session of the International Committee. It was decided also to extend the period for replies of the governments on this question to July 1, 1960.

The International Committee also discussed the question of new nomenclature for the International Scale of Temperature and adopted a resolution to call it "The International Practical Temperature Scale."

The director of the International Bureau of Weights and Measures advised members of the Committee concerning the measures taken by him in preparation of the Eleventh General Conference on Weights and Measures, set for Oct. 11 - 20, 1960. Since the quarters of the International Bureau of Weights and Measures are too small, the convention will be held in Paris in one of the halls specially built for holding conferences, with translations of all speeches. Translations into English, Russian and French was decided by the International Committee.

In accordance with the metric convention General Conferences are held once every six years and delegations from all the countries participating in the metric convention take part in them. The First General Conference on Weights and Measures was held in 1889, the last (the Tenth) in 1954. At the Eleventh General Conference, the report of the International Committee on Weights and Measures will be heard, and a number of important organizational and scientific questions in the area of international metrological work will be reviewed.

The General Conference will precede the alternate 49th session of the International Committee of Weights and Measures, called for October 4-10, 1960. The Committee will hear the report of the director of the International Bureau of Weights and Measures and discuss questions placed on the agenda of the General Conference on Weights and Measures.

The extra 48th session of the International Committee of Weights and Measures demonstrated the importance of the questions to be referred to the Eleventh General Conference on Weights and Measures (review of the metric convention, the creation of a new section on standards of measurement of ionizing radiation in the International Bureau of Weights and Measures, new definitions of the meter and the second, approval of an international system of units, the adoption of a new position regarding the International Practical Temperature Scale, etc.)

# STEPS IN IMPROVING THE QUALITY OF INSTRUMENTS ISSUED

S.A. Zabutov

From the experience of the Krasnodar State Control Laboratory
of Measuring Technique
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In the grand plan for growth of the national economy in 1959-1965, serious qualitative changes in the structure of production are contemplated.

For the further growth of industry and agriculture, complex mechanization and automation of production are being introduced more and more extensively, and the building of instruments is growing at a rapid pace.

The Krasnodar Council of the National Economy directs instrument building enterprises,which are known throughout the country, producing basic forms of electrical and weighing instruments as well as various types of testing machinery. Therefore, the Krasnodar State Control Laboratory of Measuring Technique is giving serious attention to the work of its control-inspection points. More than a quarter of all the operative-technical staff of the State Control Laboratory is working at the control-inspection points.

The Krasnodar State Control Laboratory is carefully following up the technical development of cadres by reinforcing them with respect to engineering and technical staff. At the present time more than 80% of the engineers and technicians of the State Control Laboratory are working at control-inspection points.

On the staff of engineers and technicians of a control-inspection point plant for electrical measurement instruments, the workers are exclusively specialists on electrical measurement instruments.

Control-inspection point workers, along with completion of current work,devote much attention to the study of means of utilizing the instruments produced.

Every control-inspection point is an independent section of the Laboratory and, thanks to the specialization of one enterprise or another, differs from other control-inspection points both in form and in content of the individual work.

Eight engineers and technicians work at the control-inspection point of a factory for elecrical measurement instruments ("ZIP").

Calibrating instruments and resistance instruments are subjected basically to State tests, and among them are various types of potentiometers, bridges, standard resistance coils of ten ratings. Seventy-two nomenclatures of instruments are not subjected to governmental tests, since they are transferred to the operative-technical control of the plant.

It is characteristic that during the past three years both the volume of work and the character of its accomplishment have esentially changed.

In 1957, the State Control Laboratory and control- inspection point devoted much attention to sudden revisions; less testing of current production was done. In 1958, the basic attention was directed to carrying out tests of current production and the number of sudden revisions decreased. In 1959, we renounced sudden revisions, devoting basic attention to testing of current production. In addition, State tests of single instruments were made.

We renounced sudden revisions of instruments at this factory in order to obtain the time to perform more serious work on the testing of current production, which made it possible to dismantle inadequate instruments carefully, and to find the reasons for their deficiencies.

Tests of current production are planned beforehand. After submission by instrument building plants of alternate yearly plans of the laboratories the working plan of one factory or another is designated. Also included in the plan are the graphs developed and approved of tests of current production.

In the course of further work these graphs can be changed partially, because there arises a need to perform additional tests on the basis of complaints received and for tests upon separate assignment of the Committee or an institute of the Committee.

Before carrying out tests of current production the supervisor of the control-inspection point informs the manager of the operative-technical control, who withdraws the control foremen. In the "Armalit" and "ZIM" factories a leading technologist or designer is often attached to the operative-technical worker. At the ZIP factory, tests are made only daily, since the operative-technical control worker is invited only in case of need.

Instruments are selected from current production for testing, approved by the operative-technical control and ready for shipment. As a rule these tests are made on factory testing equipment and on control-inspection point equipment. After testing, the persons who have conducted the test sign a statement and the manager of the State Control Laboratory approves the statement.

When defects are found in instruments, periods are designated for their removal and recommendations given for the improvement of various parts or units of the instrument.

The governmental testing of instruments is very laborious and responsible work.

To determine whether an instrument corresponds to new requirements of the national economy, and to the modern level of instrument building, it is necessary not only to know those conditions, but to carry out the work in cooperation with the design office and the technologists of the sections and areas of the factories.

It should be mentioned that comparison of the design of new instruments with the best domestic and foreign instruments is not always done in State testing, mainly because there are not enough materials either at the factory or at the State Control Laboratory. It is necessary to assure the State Control Laboratories of materials which uncover later attainments of instrument building technique.

In the permanently acting technical council, headed by the chief engineer of the factory, new types of instruments are systematically considered. Questions also are considered which are connected with the basis of serial production of those instruments. The supervisor of the control-inspection point must be present at meetings, or in his absence, one of the control-inspection workers.

The need for participation in the work of technical councils is furthered by many factors, a fundamental one of which is the need to be informed of new developments in measurement technique and to take steps to improve the quality of instruments.

In order to improve the designs of instruments, the State Control Laboratory studies the conditions under which they will operate.

In 1959, the State Control Laboratory directed inquiries to 65 enterprises and organizations regarding the behavior of instruments in use. The replies obtained assisted in improving several instruments.

The study by the control-inspection point of complaints coming to the factory also gives useful material. For example, unsatisfactory operation of one of the assemblies of semiautomatic potentiometer P-2/1 was eliminated as a result of combined steps taken by the factory and the control-inspection point.

Five workers make up the control-inspection point staff at the "Krasnolit" factory. Last year seven men worked there. During the year ten tests were made of current production and one State test. The order of these tests is the same as at the ZIP factory.

Due to inadequate inspection on the part of the operative-technical control at the "Krasnolit" factory a selective inspection of parts and assemblies is practiced at the place of manufacture; thanks to this, the arrival of defective products at the assembly point is reduced.

Such a type of inspection is more effective if it is carried out systematically and at vulnerable places in the productive process.

The State Control Laboratory also offers technical help in improving the design, technology and quality of instruments.

For example, in VPG-500 (m) scales with improved cross-beams, work was carried out in determining the most efficient place for location of the level.

In VTsL-10 scales the diameter was changed, the size of the end was reduced and the marking of the smallest weighing was changed from 0.5 kg to 100 kg.

In SMI-250 and SMI-500 scales stopping devices were installed and a sturdy bracing of the supporting two bands for pads put in.

Workers of the State Control Laboratory carefully approached the State testing of VPR-1 (m) scales. Before it was decided to make this in series, we studied the operation of scales of a similar system in a number of meat combines. It became apparent that the scales cannot assure increasing productivity in dressing the carcasses of cattle. On a monorail, in any case, such a quantity of rollers can be placed on which up to 0.5 ton can be hooked. As a result of our present proposal the monorail was lengthened and the balance beam and driving gears throughly changed.

VPR-1 (m) scales now being issued meet the requirements of the meat combines.

For a more complete picture of the work of the control-inspection point at the "Krasnolit" factory it should be mentioned that the inspection of the VPG-500 (m) scales was conducted by us on a conveyer in a cycle of its operation with an output of up to 100 units per shift.

The control-inspection point in Armavir serves two plants, the "Armalit" producing travelling scales, automobile scales for weighing cattle, gears, UM-5 machines and MK-30A pendulum frames, and a testing machinery plant. A senior engineer manages the control-inspection point of the "Armalit" factory, acting simultaneously as the supervisor of the very large permanent State Control Laboratory in the region. This combination enables simplification of guidance by small sections of the Committee system. The automotive and travelling scales are put on stands and are not stamped, since the final testing is repeated when they are installed at the place of use.

At the "Armalit" factory we repeatedly have set up the problem of improving the quality of the enclosures on scales for weighing cattle, and recently, of replacing these scales, which have a balance beam, with dials, which should increase the output in weighing cattle and improve the operating conditions.

At the present time a model of these scales which takes our comments into consideration is being produced.

After a number of comments on cleanliness, of the polishing of the surface of the pads, the period of manufacture and introduction of a special stand was agreed upon with the factory.

A great amount of work has been carried out by the State Control Laboratory and control-inspection points at Armavir on the improvement of the quality of the UM-5 testing machine.

It must be noted that inadequate attention is being given to the quality of the product on the part of factory workers in the "Krasnolit" and "Armalit" factories. Thus the "Armalit" plant, in 1958 alone, paid more then 7000 rubles in state dues for repeated presentation of instruments for State checking.

It is difficult to reveal in a single paper all the work being done at the Krasnodar factories by the State Control Laboratory with the help of its engineers and technicians.

The State Control Laboratories of Measuring Technique are making a great contribution to the raising of the quality of the instruments that are being produced.

# IMPROVING THE QUALITY OF INSTRUMENTS FOR MEASURING PRESSURE

N.I. Zhukovskii

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The tasks set by the Twenty-first Congress of the Communist Party of the Soviet Union, the June (1959) and July (1960) Plenums of the Central Committee of the Communist Party of the Soviet Union regarding the widespread introduction of complex automation of productive processes require definite improvement in the quality of measuring instruments.

The organs of the Committee on Standards, Measures and Measuring Instruments are systematically checking the quality of measuring instruments now being issued by factories and are also studying the instruments now in use.

As a result of checking, it has been established that a number of serially produced instruments do not satisfy the requirements of the national economy as regards quality.

The quality of instruments for measurement of pressure, vacuum, head and flow of liquids and gases calls for a special designation.

Defects in instruments with sensing elements (instability of readings, refusal to workdue to malfunction of the sensing elements, fractures and deformations, the withdrawal of pointers from the zero position, instability of operation under conditions of vibration, premature malfunction during use of agressive and viscous media) are the result of inappropriateness and disruption of the technological process of manufacturing of sensing elements, and are further brought about by the absence of experimental and research work during the selection of the starting materials for these elements.

Thus, up to 50% of the manometers produced by the Tomsk plant in 1959 go out of order within four to eight months after being put in use, and up to 10% the readings change even before being put in use, whereas they should operate without failure for not less than three to five years.

The severe worsening in the quality of manometers was the result of change by the Tomsk factory of the design of the instruments approved in state tests in 1948-1949, and had the result of a profound disruption of the technological processes in the manufacture of the corresponding assemblies and parts of the instruments. Lengthy factory, state and practical tests did not precede the introduction of the manometers of modified design into production.

The basic design modifications were directed toward reduction of weight and lowering the cost, but at the expense of the deterioration in quality and reliability of operation of the instruments under conditions of use. Thus the frame was previously fastened to the holder by three bolts, and prior to 1959 was fastened by screws inserted 0.5 of the length of threaded openings in the holder; the fastening of the dial was done at two points with a bearing on the unworked surfaces; the frame of the instrument did not protect the mechanism and the scale from soiling; the possibility of escape of gases if the tubular spring were broken was not provided for; the fastening of the driving mechanism was not secure; the free ends of the steel tubular springs were welded, and the springs could not be cleaned during maintenance.

The design of the frame and the means of fastening the glass, being unreliable, not only made checking them difficult but led to fracture of the glass and premature malfuction of the instruments.

The technological processes of manufacture of the corresponding assemblies and parts became obsolete and severely worsened the quality of the instruments produced.

For example, in the assembly plant, to assure the smooth movement of the mechanism the engagement of the massive brace and settling of the toothed sectors was done with hammers.

In the standardizing and tube hardening section, the instruments used for control of the technological process had an error four to five times the permissible.

The technological equipment (jigs and dies) were severely worn. The processes of mechanical aging of steel springs for high pressure manometers were not known, nor were the production of manometer springs without a filler and bright hardening of steel manometer springs.

The factory's change of the assemblies and parts did much material damage to the national economy. The losses due solely to premature repair of the Tomsk factory's manometers amounts to not less then ten million rubles per year for the entire country.

Thanks to the help of the Tomsk Council of National Economy and the Party organs, as a result of the action of the Committee of Standards, Measures and Measuring Instruments, the factory has raised the quality of the manometers being issued.

At the factory a new design for manometers in ordinary use was created and new technological processes were introduced: the bending of manometric steel and brass springs without preliminary heating and without a filler (the sandless method) on semiautomatics created by the factory, and this improved the stability and steadiness of the readings on the instruments. At other factories, however, they are introducing this process very slowly and, at others, they know nothing about it.

The introduction of punching and repassage of openings in plates and the polishing of axle joints and driving gears has assured the interchangeability of parts of the gear mechanism and permitted the elimination of delay and settling of the gears with hammers.

The introduction of furnaces equipped with instruments for the automatic control of temperature during thermal operation of the manometer springs has improved considerably the quality of manometer springs.

The equipment of the control-testing laboratories with new devices for the testing of instruments on a jolting conveyor, the resistance to vibration, the action of variable pressure, the safety factor of the springs and the contemplated specification of State All-Union Standard 8625-59 has enabled the factory to study and eliminate deficiencies in the instruments.

The laboratory created in 1959 and the experimental section have made it possible to begin research and experimental work on the establishment of an efficient technological process in manufacturing manometer springs.

It is intended in 1960 and 1961 to become familiar with a number of new instruments provided for by Standard 8625-59.

It is necessary to develop experimental models and prepare the serial production of instruments with increased accuracy of classes 1 and 1.5, to work out and implement the production of instruments resistant to mechanical effects - jolts, vibration, shock, to unify instruments according to adjoining and profile dimensions and also to enter upon research and experimental work on the selection of starting materials for the creation of instruments which are stable to aggressive and viscous media.

The absence of designs of instruments for the measurement of pressure and vacuum of aggressive and viscous media, and resistant to mechanical action obliges consumers to use instruments of general industrial designation in ordinary usage, which leads to considerable shortening of their service life.

To develop and introduce into production new first-class instruments, it is necessary to expand and reinforce the personnel of the central design and laboratory sections and to attract scientific research organizations for joint work. To put high-quality manometer springs into production, it is necessary to organize a factory metallographic and mechanical laboratory. The organized productive areas of the factory hinder the elevation of the culture of production and improvement in the quality of instruments. The Tomsk Council of National Economy must complete more quickly the construction of new buildings of the enterprise and the transfer of it to a new area.

In parallel with testing the quality of instruments issued by the Tomsk factory the Committee has conducted a test of the quality of instruments issued by the Moscow "Manometr" factory. It was established by checking that 50% of the manometric electrocontact thermometers exceeded the established norms of accuracy

by twice, and 15% of the thermometers were rejected because of unsealed hermetic systems; all the pressure gauges subjected to test at 15,000 cycles of variable pressure with subsequent checking of them in accordance with the fundamental error fail to meet the specifications of the standard both as to fundamental error and to stability of the readings.

The correcting apparatus on all the instruments operated unreliably, and as a result the pointers were systematically displaced from the zero position.

In 66% of the electrocontact manometers with a limit of measurement of 1000 kg-wt/cm$^2$ in testing them at the upper limits of measurement without preheating there was a fracture of the brass springs; 66% of the manometers with a limit of measurement of 60 kg-wt/cm$^2$ during testing at 15000 cycles of variable pressure and subsequent checking of them for accuracy of the readings, exceeded the permissible error by 160%.

During selective testing of 26 control and 30 standard manometers, it was found that 50% of the control manometers exceeded the established norms of accuracy by twice; all the manometers subjected to testing at + 60° and subsequent testing at normal temperature (+20°C) exceeded the allowances for change by 40 to 60% above the set values; 20% of the standard manometers did not meet the specifications of Standard 6521-53 on shift of the pointer from the zero position and disperison of the readings; all the standard manometers, after their testing for overloading and exposure for fifteen minutes and subsequent testing failed to meet the requirements of the standard for variation of readings and displacement of the pointer from the zero position. All these defects and violations of the requirements of the standards appeared in instruments inspected by the operative-technical control.

According to the records of a control point of the Committee of Standards, Measures and Measuring Instruments, which had made a check of every standard manometer, the return of instruments to the assembly plants in 1957-1958 amounted to 20-25%; of the instruments returned 80% were rejected because of poor quality in the manufacture of the sensing elements; in 1959, 9.4% of the manometers were returned.

In differential manometers DM-6 with secondary EPID instruments the control went out of order after brief use, and as a result, the norms for accuracy and the constancy of zero were not maintained.

In 1959 the quality of standard and control manometers was improved somewhat at the "Manometr" factory. But the basic problem, that of providing the national economy with control and standard manometers of high quality, was not solved by the factory. No tests were made at the factory for stability of readings, transport jolts, vibrations, etc. A laboratory of sensing elements has not been organized up to the present time.

In 1959 the factory transferred the production of electrocontact manometers, manometric thermometers and suction pressure gages not utilized entirely for production to other enterprises. It is necessary that the State Planning Commission of the Russian Soviet Federated Socialist Republic require factories to transfer for production by other enterprises only what is utilized production.

In connection with the approval of the Committee of Standards, Measures and Measuring Instruments of a new standard for master and control manometers in vacuum gages from the collective of the "Manometr" factory, intense work is required upon considerable improvement of the quality of the instruments and of familiarity with standard instruments of classes 0.16 and 0.25 which are needed in checking instruments of class 0.5; it is also necessary to extend the limits of measurement of instruments up to 1000 kg-wt /cm$^2$. The factory has to prepare a number of testing devices, among them some for the testing of instruments for the effect of variable pressures, transport jolts, etc.

At the Kazan "Teplokontrol'" factory, 60% of the small-scale manometers in a frame with a 60 mm diameter and limits of measurement of 100 to 250 kg-wt/cm$^2$ exceeded the permissible norms of accuracy by 50% during testing dynamically by the effect of variable 15,000 cycle-pressure and subsequent testing for fundamental error; this was the result of deformation of the sensing elements (Bourdon tubes). Of the recording manometers, 50% did not meet the specifications of Standard 7919-56 for norms of accuracy and displacement of the pointer from zero position, exceeding the permissible norms by 50-100%. Of the manometric thermometers, 50% exceeded the specifications set by Standard 8624-57 by 70% in a test for stability of the readings.

The Kazan "Teplokontril'" factory, in addition to improvement of the quality of the small-scale instruments of class 4 now being produced serially, has to become familiar with the production of small-scale manometers of classes 2.5 and 1.5, and in about two to three years will have to replace obsolescent differential mercury manometers with those not containing mercury, set up the production of compensating differential manometers of

classes 0.5 and 1, whose sensing elements are sylphons and membranes. It is therefore necessary to organize a sensing elements laboratory at the factory.

The experience of the Tomsk factory should be taken into consideration, when scientific research organizations and specialists in Kazan extend help to the factory in working out and becoming familiar with high quality sensing elements.

The data concerning the low quality of the small-scale and recording manometers and manometric thermometers issued by the Kazan "Teplokontrol'" factory is confirmed by reports received by the Committee from enterprises and the State Control Laboratory of Measuring Technique, which made direct observations of the work of the instruments under conditions of use.

Over a period of years the medical instrument factory "Krasnogvardeets" and the sanitary and medical equipment plant at Odessa have been producing membrane instruments for measuring blood pressure, with a dispersion of readings up to 25 mm of Hg instead of ± 5 mm of Hg according to Standard 6915-59.

The Committee of Standards, Measures and Measuring Instruments, by agreement with the Ministry of Public Health of the USSR, forbade the production of instruments in these factories. The issuance of instruments has not been resumed up to this time and they have been replaced by mercury instruments which are inconvenient to use and harmful to the health.

The issuance of profile suction pressure gauges, pressure gages and suction gages for limits of measurement up to 40 mm of Hg has been forbidden at the Khar'kov control-measuring instrument factory; these are necessary in many branches of the national economy for the control of pressure in the working space of industrial furnaces and evacuation in the combustion chamber of pressure boilers. The instruments are unstable in readings and the norms of accuracy change very sharply at a temperature of + 60°C.

The Rizhsk factory "Avtoelektropribor" issues piston-type manometers for automobile tires, whose readings change sharply; as a result of incorrect measurement the pressure of the tire deteriorates prematurely. The measurement of pressure in tires with an accuracy of 0.1-0.2 kg-wt/cm$^2$ enables one to increase the life of the tire by 7-10%. To do this the piston-type manometers must be replaced by sensing elements (Bourdon tube).

In carrying out State tests of 15 instruments from the "Tizpribor" factory the errors of ten instruments were more than twice the permissible, the instrument readings were unstable, the instruments exhibited did not pass the tests for variable pressure, in five instruments the belt rods broke.

Taking into consideration the need for a sharp elevation of the quality of instruments, the Committee of Standards, Measures and Measuring Instruments reviewed in 1959-1960 the standards for manometers, vacuum manometers and vacuum gauges in common use and also for control and master manometers and vacuum gauges having specified in Standards 6400-60, 6521-60, and 8625-59 the gradual pointers (the testing of instruments in a dynamic cycle under the effect of variable pressures, the testing of instruments for stability of readings under overload, etc.) and having unified them with the standards of countries of national democracy regarding limits of measurement, classes of accuracy and small-scale dimensions. A plan for a standard for a differential manometer is provided.

At the present time the NIITI Scientific Research Institute of Measuring Technique for instruments has set up arrangements for the testing of instruments for variable pressures with a limit measurement up to 5000 kg-wt/ /cm$^2$. The State Planning Commission of the Russian Soviet Federated Socialist Republic must in the very near future try to find methods for their centralized production.

Not a single factory or institute in the industry is occupied with the further development of methods and means of forced testing of instruments under factory conditions.

The basic reason for the low quality of the instruments issued by the industry is the inadequate efficiency and low resilient properties of the brass springs. The resilient properties of sensing elements is considerably increased if dispersion-hardening steel and bronze are used (for example, stainless steel ÉI-702, beryllium bronze BNT and INM 20-20, etc.).

New dispersion-hardening alloys meet more fully the requirements set forth for resilient sensing elements. Thus the limit of proportionality of springs can be increased by 1.5-2 times by change of the material, while at

the same time the amount of hysteresis is reduced. The lasting quality and stability of resilient sensing elements is increased by several times, and this leads to increased reliability during use and of stability of the characteristics of the instruments.

But the new alloys have not yet been introduced into the instrument building industry. Work on resilient sensing elements is being done by many organizations without coordination and this leads to parallelism, hinders the normalization and standardization of these elements and does not create the prerequisites for centralized production on the basis of progressive technology. The technology of production in a number of instrument building factories does not assure high quality of the resilient sensing elements.

Research on the development of single metrological norms, methods of stabilization and testing of resilient sensing elements and raw materials is being carried out in an extremely weak manner.

All this leads to the fact that many instruments with resilient sensing elements do not have adequate accuracy, stability of characteristics and reliability in use.

The low quality of resilient sensing elements lowers the service life of instruments, which as a rule does not exceed one year. As a result, vast amounts are expended on repair and the requirements for new instruments in production are increasing. Raising the quality of the brass springs in manometers will make it possible to save more than 60 million rubles per year, will curtail the issue of manometers, and factories will be able to issue instruments for which the need has been far from satisfied.

Delay in making use of serial issue of stainless steel sylphons of high quality is holding up the production of new models of differential manometers. Discontinuance of the production of obsolete differential mercury manometers will permit an annual saving of up to 150 tons of mercury and improve the working conditions of several thousand persons. The economic effectiveness of using sensing elements will be even higher if it is considered that more precise and reliable control and regulation will be effected by their use in various productive processes. To improve the quality of instruments which have resilient sensing elements it is necessary to revise Standard 2622-44, supplementing it with a point regarding the use of dispersion-hardening alloys.

It is necessary to create and reinforce the factory sensing element laboratories with qualified specialists and to provide them with new and modern equipment.

A united design and technological bureau must be created, which would concern itself with research on sensing elements and their assemblies and on materials for them, with the creation of elements of all types and sizes and the development of technological processes for the manufacture of elements and a single method of testing them. The great work of the Design-Technological Bureau should be carried out in the area of standardizing, normalizing and unifying sensing elements and their assemblies. For the coordination of efforts in the area of creation of sensing elements and their introduction into production, all the corresponding work should be cleared with the Design-Technological Bureau.

This is a far from complete summary of the steps required for raising the stability of readings, the precision and reliability in use of a much more extensively used group of instruments, manometers, vacuum manometers, vacuum gauges, manometric thermometers, barometers, level gauges, flowmeters, altimeters, suction pressure meters, speed indicators, hydraulic flow regulators, pneumatic controls, instruments for measurement

# TESTING PLANS DEVELOPED BY THE D.I. MENDELEEV ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF METROLOGY

K.P. Shirokov

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Testing plans are documents which set up the sequence and accuracy of transfer of units of measurement from the calibrators to standards and from them to operational measures and measuring instruments. They must serve as the guiding material in questions of selection of the means and methods of testing measures and measuring instruments.

The first suggestions for the makeup of testing plans were expressed by Professor L.V. Zalutskii, who developed the first testing plan (in the area of linear measurements). Later, testing plans were also composed in a few other areas, in which Professor M.F. Malikov exercised general supervision of their composition. He defined more accurately the principle of construction of testing plans and worked out "Aspects of calibrations and divisions of standard measures and measuring instruments" [1], by which testing plans were allotted a definite place in the number of normative documents directed toward assurance of harmony of measurements in this country.

Examples of testing plans in their original form are given in [2], and somewhat later some plans were included in [3].

For purposes of broad discussion a collection was published in 1956, composed by associates of the D.I. Mendeleev All-Union Scientific Research Institute of Metrology [4]. Twenty-three plans published in the form of a plan with explanatory text nevertheless found application in testing practice and in the establishment of instructions for the testing of measures and measuring instruments. Testing of the plans in the course of current work and the observations obtained have enabled more prevision to be introduced and plans to be prepared for approval as official documents of the D. I. Mendeleev All-Union Scientific Research Institute of Metrology. A number of new plans have also been composed which were absent from the 1956 collection.

Collections of testing plans as guide material, although known to us, have not been published abroad.

In 1960 there was published a collection of testing plans prepared by the D.I. Mendeleev All-Union Scientific Research Institute of Metrology, containing 34 plans approved by the director of the Institute.

| Number | Name of testing plan | Reference standard for testing plan | Range of values attainable by standard measures and instruments | Error in testing of the most accurate first-class measures | Errors of the most accurate operating measures and measuring instruments | | Notes |
|---|---|---|---|---|---|---|---|
| | | | | | permissible error | limiting error of the testing | |
| 1 | Testing plan for hatched measures of length | State standard: platinum-indium meter No. 28 | 10 mm–20m | $6 \cdot 10^{-5}$ % | – | $1 \cdot 10^{-4}$ % | – |
| 2 | Testing plan for plane-parallel terminal measures of length and instruments for measurement of linear dimensions | Standard method of reproduction of a meter in light wavelengths | 0.1 mm–2 m | $5 \cdot 10^{-5}$ %• | $4 \cdot 10^{-4}$ % | – | •The error caused by instability of the measure is included in this value |

| Number | Name of testing plan | Reference standard for testing plan | Range of values attainable by standard measures and instruments | Error in testing of the most accurate first-class measures | Errors of the most accurate operating measures and measuring instruments | | Notes |
|---|---|---|---|---|---|---|---|
| | | | | | permissible error | limiting error of the testing | |
| 3 | Testing plan for angular measures and angle-measuring instruments | Standard method of reproduction of the unit of the plane angle with a polyhedral prism and autocollimators | 0–360° | 1" | 1' | – | – |
| 4 | Testing plan for weights and scales (balances, dials and automatic) | State standard: platinum-iridium kilogram No. 12 | 0.5 mg–80 t | $5 \pm 10^{-5}$% | – | – | The value $5 \cdot 10^{-5}$% refers to first class weights which can be tested directly on working standards |
| 5 | Testing plan for areometers | Standard method of reproducing the unit of density (weight) | 0.65–2.0 g/cm$^3$ | 0.005% | 0.01% | – | – |
| 6 | Testing plan for measures of capacity and instruments(for measuring volumes of liquids and gases) | Standard measures of mass (for certain tests of standard measures of length) | 0.5 cm$^3$–11 m$^3$ | 0.015% | – | 0.05% | – |
| 7 | Testing plan for clocks and other instruments for measuring time | Standard method of reproducing the unit of time and frequency on the basis of stellar observations | – | 0.003 sec | 0.5 sec | – | The indicated mean-square difference of adjacent daily paths |
| 8 | Testing plan for measures of frequency and frequency-measuring instruments | Same | 15 cps–50,000 Mc | $1 \cdot 10^{-4}$% | $1 \cdot 10^{-5}$% | – | The value $1 \cdot 10^{-5}$% refers to piezoelectric crystals which can be tested directly on working standards by translation of the frequencies |

| Number | Name of testing Plan | Reference standard for testing plan | Range of values attainable by standard measures and instruments | Error in testing of the most accurate first-class measures | Errors of the most accurate operating measures and measuring instruments | | Notes |
|---|---|---|---|---|---|---|---|
| | | | | | permissible error | limiting error of the testing | |
| 9 | Testing plan for excess pressure manometers, vacuum manometers and vacuum gauges | State standard: a group of five heavy-piston manometers with limits of measurement of $1.10^5$ to $60.10^5$ n/m$^2$ (from about 1 to 60 kg-wt /cm$^2$) | 760 mm Hg — 16000 kg-wt /cm$^2$ | 0.02% | 0.5% | – | – |
| 10 | Testing plan for micromanometers and differential manometers | Working standards: instruments of calibrating heavy-piston manometers or standard measures of length and mass | 0–1200 mm $H_2O$ | 0.02% | 0.5% | – | – |
| 11 | Testing plan for absolute pressure manometers | Standard measures of length and mass, and also standard thermometers | $10^{-7}$–10 mm Hg | 1% | 3% | – | – |
| 12 | Testing plan for acoustic measuring instruments | Standard method of reproducing the unit of sound pressure by means of 1) a 5-100 cps hydraulic press; 2) an assembly of sound measuring discs from 20 cps to 30 kc; 3) reversible electroacoustic transformers from 500 cps to 300 kc; 4) an assembly of acoustic radiometers from 100 to 1000 kc | 5 cps–1000 kc | 3% | – | 12% | – |
| 13 | Testing plan for power measuring machines and instruments | State standard: an assembly of measures of power in arrangements for reproducing the value of power from 0.2 to 10 ton-wt and 1 to 100 ton-wt. For some tests the highest designation is the standard weight and also the standard measure of length and the standard heavy-piston manometer | 0–100 ton-wt | 0.1% | 1% | – | – |

| Number | Name of testing plan | Reference standard for testing plan | Range of values attainable by standard measures and instruments | Error in testing of the most accurate first-class measures | Errors of the most accurate operating measures and measuring instruments | | Notes |
|---|---|---|---|---|---|---|---|
| | | | | | permissible error | limiting error of the testing | |
| 14 | Testing plan for instruments and measures of hardness | State standards: 1) an instrument for measuring hardness on the Rockwell and Super-Rockwell scales; 2) the same on the Vickers scale; 3) the same on the Brinell scale | 20–70 HRC<br>8-1000 HV<br>8- 450 HB | 0.3-0.4 units HR for measures on the Rockwell scale, 0.5% on the Vickers, and 1% on the Brinell | Rockwell 1 unit, Vickers 2%, Brinell 3% | – | The values on the graph "Error in Testing," refer to the attainable dispersion |
| 15 | Testing plan for viscosimeters | Standard method of reproducing the unity of viscosity based on the period of discharge of water and accessory liquids | $1 \cdot 10^{-6}$–0.01 $m^2$/sec | 0.2% | – | 0.5% | – |
| 16 | Testing plan for instruments measuring roughness of a surface | Standard interference method of measuring roughness | 1–14th grades | 1.5% | – | 10% | – |
| 17 | Testing plan for tachometers and speedometers | Standard measures of frequency: piezoelectric crystal generators | 0–60,000 rev/min | 0.01% | 0.5% | – | – |
| 18 | Testing plan for calorimeters | Standard measures of dc resistance and frequency and standard thermometers | 26435 ± 132 joules | 0.03% | – | 0.3% | – |
| 19 | Testing plan for thermometers and pyrometers | Standard method of reproducing the temperature scale according to six constant points | 10°K–2800 °C | 0.004°C | 0.02°C | – | – |
| 20 | Testing plan for measures and instruments for the measurement of electrical resistance | State standard: a group of four standard one-ohm resistance coils | $1 \cdot 10^{-6}$–$1 \cdot 10^{14}$ ohms | $2 \cdot 10^{-4}$% | 0.001% | – | – |
| 21 | Testing plan for inductance coils which measure and instruments for measurement of inductance | State standard: a group of four standard inductance coils | $1 \cdot 10^{-7}$–100 henries | 0.01% | 0.1% | – | – |
| 22 | Testing plan for condensers which measures and instruments for measurement of electrical capacitance | State standard: a group of six standard condensers | $1 \cdot 10^{-3}$ μμf 100 μf | 0.02% | 0.05% | – | – |

| Number | Name of testing plan | Reference standard for testing plan | Range of values attainable by standard measures and instruments | Error in testing of the most accurate first-class measures | Errors of the most accurate operating measures and measuring instruments | | Notes |
|---|---|---|---|---|---|---|---|
| | | | | | permissible error | limiting error of the testing | |
| 23 | Testing plan for standard cells | State standard: a group of 20 calibrating standard cells | ~1 v | $2.10^{-4}$% | 0.001% | – | – |
| 24 | Testing plan for voltmeters | Standard measures of dc: standard cells | 0–100,000 v | 0.003% | 0.1% | – | – |
| 25 | Testing plan for ammeters and counters of the quantity of electricity | Standard measures of dc and resistance: standard cells and resistance coils | 0–100,000 amp | 0.03% | 0.1% | – | – |
| 26 | Testing plan for wattmeters and counters of electrical energy | Standard measures of dc: standard cells and resistance coils | 0–10 watts | 0.003% | 0.1% | – | – |
| 27 | Testing plan for measures of voltage of a magnetic field and a magnetic flux | State standard: calibrating coil for the voltage of a magnetic field (Helmhotz) with a diameter of 300 mm | 5–1000 oe<br>0.001–0.1 weber | 0.02% | – | 0.2% | – |
| 28 | Testing plan for light-measuring lamps and instruments | State standard: full emitter at the hardening temperature of platinum | 5–1000 int. candles<br>10–3500 lumens | 0.25% | – | 0.3% | – |
| 29 | Testing plan for sensitometers | Standard light-measuring lamps | 0–300 Gostunits and more | 2% | 10% | – | – |
| 30 | Testing plan for roentgenometers and dosimeters of X-and gamma radiations and for gamma emitters | Standard method of reproducing Roentgen units upon ionization of air for radiations with energy quanta of 5 to 3000 kev | 160-1000 r/sec (depending on the quantum energy) | 2% | – | 5% | – |
| 31 | Testing plan for radioactive preparations, graduated in units of activity | Standard method of reproducing units of activity by determining the number of acts of decomposition | $10^{-11}$–100 curies | 2% | – | 5% | 5% is the limiting error of the testing of the emitter |
| 32 | Testing plan for radioactive preparations graduated in units of radium gamma-equivalent | State standard: radium X1 preparation | $10^{-5}$–500 mg radium | 1% | – | 1.5% | 1.5% is the limiting error of calibration of the working radioactive preparations |

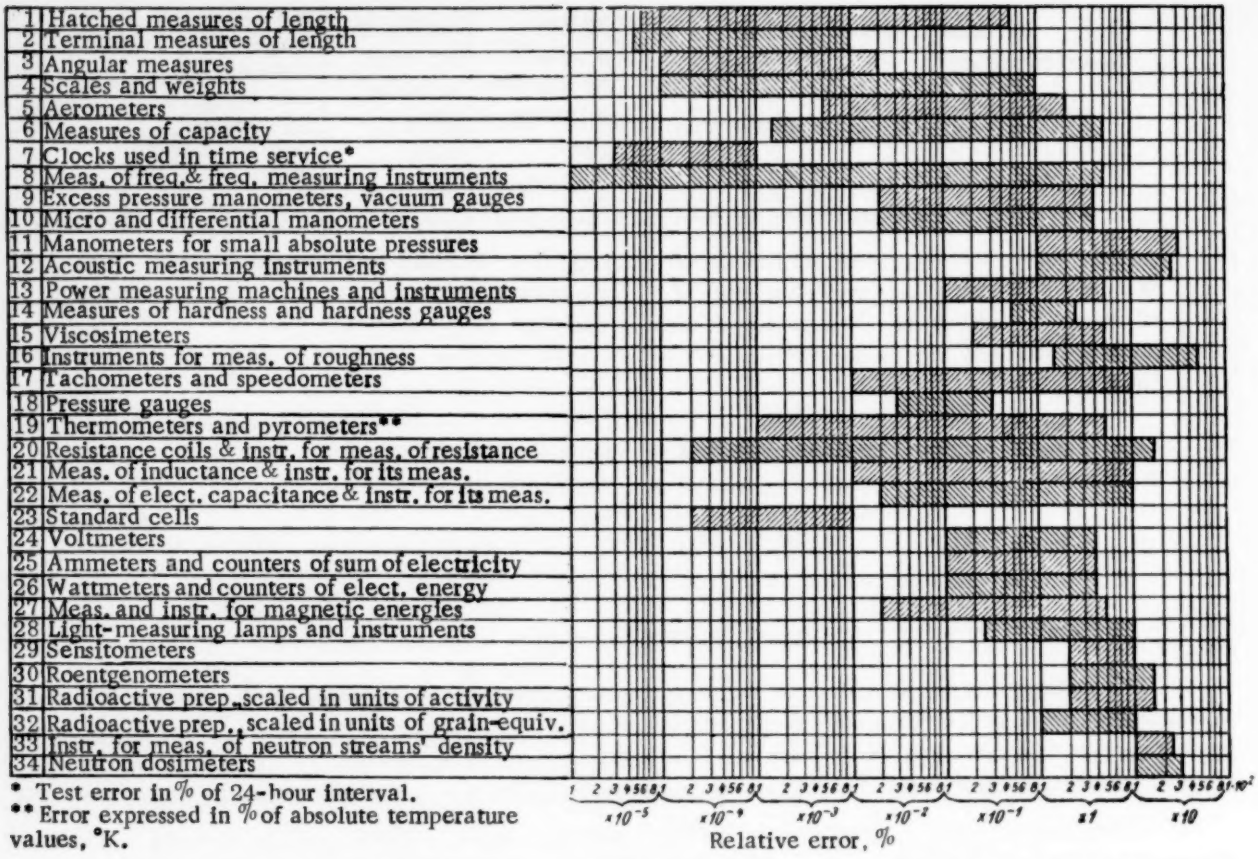
| Number | Name of testing plan | Reference standard for testing plan | Range of values attainable by standard measures and instruments | Error in testing of the most accurate first-class measures | Errors of the most accurate operating measures and measuring instruments | | Notes |
|---|---|---|---|---|---|---|---|
| | | | | | permissible error | limiting error of the testing | |
| 33 | Testing plan for sources of neutrons and instruments measuring the density of neutron streams | Standard method of reproducing units of density of a neutron stream | $1-10^{10}$ neutrons/ $cm^2 \cdot sec$ | 10% | – | 15% | 15% is the limiting error of testing operating instruments |
| 34 | Testing plan for neutron dosimeters | Standard method of reproducing units of a neutron dose | $20-10^{10}$ neutrons/ $cm^2 \cdot sec$ | 10% | – | 25% | 25% is the limiting error of testing operation dosimeters |

The testing plans in the collection are graphic presentations of the coordination of standards and standard measures and the sequence of transfer of units of measurement by various forms of operating measures or measuring instruments with indication of the basic methods and the accuracy of the test. As a rule each testing plan provides for the transfer of units of a single measurable value. The plans are accompanied by explanatory texts.

The testing plans were constructed in the following way. Primary standards or the standard methods replacing them were placed in the upper part of the field of the plan set aside for the standards. The secondary standards were placed below the primary standards in the same field. The full names of the standards were put in the plans with indications of their forms (primary standard, standard-witness, standard-copy, operating standard). Below the field of standards there are placed fields of classified standard measures and standard measuring instruments according to the number of classes possessed. Still further down is the field of operating measures and measuring instruments encompassed by a given plan.

Coordination of measures and measuring instruments is shown by the lines joining them, passing through the circle in which the methods of transferring units are indicated. The basic methods of testing are: a) direct (that is, without the help of any comparing instrument) comparison of the measuring instruments (and sometimes of the measures) with one another; b) comparison of measures by means of some sort of comparator; c) testing of a measuring instrument by the action on it of a physical value reproducible by a standard measure ("testing according to a standard measure"); d) direct measurement by standard measuring instruments of a value reproducible by the measure being tested. It is natural that in the plans these basic methods are made concrete as regards the characteristics of various forms of the means of measurement.

The designations of standard measures in the plans are accompanied by an indication of the limiting error $\delta_{np}$ of the transfer of the unit from a higher section of the plan to a given measure (of the measuring instrument). The values of the limiting error of testing of standard measures was established on the basis of experimental data accumulated in the laboratory of the D.I. Mendeleev All-Union Scientific Research Institute of Metrology. The testing errors of standards are not indicated in the plans since they cannot be set and are determined during each investigation of the standard by working up the results obtained. Obviously the errors of the standards should lie within the limits which assure testing of lower standard measures, with errors not exceeding the values indicated in the testing plans, and therefore should directly succeed the Institute's laboratory which retains the primary standards.


1 Hatched measures of length
2 Terminal measures of length
3 Angular measures
4 Scales and weights
5 Aerometers
6 Measures of capacity
7 Clocks used in time service*
8 Meas. of freq.& freq. measuring instruments
9 Excess pressure manometers, vacuum gauges
10 Micro and differential manometers
11 Manometers for small absolute pressures
12 Acoustic measuring instruments
13 Power measuring machines and instruments
14 Measures of hardness and hardness gauges
15 Viscosimeters
16 Instruments for meas. of roughness
17 Tachometers and speedometers
18 Pressure gauges
19 Thermometers and pyrometers**
20 Resistance coils & instr. for meas. of resistance
21 Meas. of inductance & instr. for its meas.
22 Meas. of elect. capacitance & instr. for its meas.
23 Standard cells
24 Voltmeters
25 Ammeters and counters of sum of electricity
26 Wattmeters and counters of elect. energy
27 Meas. and instr. for magnetic energies
28 Light-measuring lamps and instruments
29 Sensitometers
30 Roentgenometers
31 Radioactive prep., scaled in units of activity
32 Radioactive prep., scaled in units of grain-equiv.
33 Instr. for meas. of neutron streams' density
34 Neutron dosimeters
1 2 3 4 5 6 8 1 2 3 4 5 6 8 1 2 3 4 5 6 8 1 2 3 4 5 6 8 1 2 3 4 5 6 8 1 2 3 4 5 6 8 1 10²
×10⁻⁵ ×10⁻⁴ ×10⁻³ ×10⁻² ×10⁻¹ ×1 ×10
Relative error, %

* Test error in % of 24-hour interval.
** Error expressed in % of absolute temperature values, °K.

Working measures and measuring instruments are characterized by an indication in the plans of categories of accuracy set for them by the State standards. In cases where the categories of accuracy for a given type of measures or instruments have not been established their accuracy is characterized in another way, for example by indication of the value of a division of the scale or the permissible error $\delta_{np}$ established for them. In some cases, when permissible errors have not been established, limiting test errors $\delta_{np}$ have been indicated for operating instruments analogously to the standards. As an exception, for individual types of measures which do not have divisions as regards accuracy, the errors are generally not indicated.

Testing plans are accompanied by explanatory texts to which brief notes are added on the plans where necessary. In the texts more detailed information is given regarding standards and standard measures, and likewise of certain methods of testing. In addition there is a listing of the establishments of the Committee of Standards, Measures and Measuring Instruments in which these or other standards and standard measures and measuring instruments are kept, tested and used.

The collection includes 34 testing plans embracing every basic area of measurement: linear and angular measurements, measurements of mass, density and capacity, measurements of time and frequency, electrical and magnetic measurements, measurements of temperature and the heating value of fuel, photometry and measurements of ionizing radiations. The table gives a summary of the testing plans included in the collection and of certain information which characterizes the plans.

The diagram presents the ranges of accuracy of the means of measurement (with the exception of the standards) encompassed by the testing plans included in the collection of testing plans issued by the D.I. Mendeleev All-Union Scientific Research Institute of Metrology (the designations of the plans are given in abbreviated form). The hatched bands indicate the intervals of the relative errors characteristic of the means of measurement included in the testing plans. Naturally the diagram can give only a general presentation of the spectrum of accuracy in the various areas of measuring technique, but all the same it reflects to a certain degree the relationship of the accuracies which are mainly determined by the very nature of the measurable quantities, and the levels of accuracy of their measurements as required in practice.

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# LINEAR MEASUREMENTS

## INVESTIGATING DYNAMIC ACCURACY CHARACTERISTICS OF PNEUMATIC TRANSDUCERS FOR AUTOMATIC CHECKING OF DIMENSIONS

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The Chinese People's Republic
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The dynamic error of a transducer is understood to consist of the difference between the ideal reading in a static condition and the reading obtained in a dynamic condition of the transducer for the same input parameters.

The dynamic characteristics give a realistic estimation of the accuracy which will be provided by the transducer when it is connected to a system of automatic control, since these characteristics are obtained under conditions approximating those prevailing in operation.

Various types of automatic control devices require suitable dynamic accuracy characteristics.

As the result of our computations and tests, we recommend the following dynamic accuracy characteristics for pneumatic contactless transducers:

1) a transition accuracy function, which represents the law of measuring a suddenly applied variable under test assumed to be equal to unity, as it is normally done in automatic control devices; 2) an amplitude-frequency accuracy characteristic, which represents the relation between the amplitude of readings and the angular frequency of the continuously measured variable, as in automatic control of machining or of the geometric shape of components.

A more detailed illustration of these characteristics is provided by their application to a concrete case of a pneumatic transducer shown in Fig. 1.

Transition accuracy function. If the transducer alone is considered the term of the third derivative is neglected, since it is small, and the effect of the pneumatic system which consists of the tubing and nozzles is ignored, the differential equation of the displacement of the moving part will have the form:

$$M_r S+DS+KS=\Delta p_1(t)\pm\delta p_{st} \qquad (1)$$

where $M_r$ is the mass of the system referred to the unit effective area of the bellows; D is the damping coefficient, which depends on the coefficient of the gas dynamic resistance of the transducer proper, the volume of the bellows chamber and other factors, referred to the unit effective area of the bellows; K is the stiffness coefficient of the elastic system referred to the unit of the effective area of the bellows; $\Delta p_1(t)$ is the variation of pressure related to the variation of the measured dimension; $\pm\delta p_{st}$ is a static error expressed in kg-wt/cm$^2$.

In order to determine the transition accuracy function of the transducer, let us first determine the transition function of the transducer proper:

$$F(p)=\frac{1}{M_r\ (p^2+2ap+\omega_0^2)}, \qquad (2)$$

where

$$2a=\frac{D}{M_r};\ \omega_0^2=\frac{K}{M_r};$$

p is the differential operator.

Then the translation accuracy function of the transducer will be:

$$\Delta S_1(t) = L^{-1}[F(p) - F_{st}] =$$

$$= \frac{1}{M_r \omega_0^2}\left[1 - \frac{\omega_0}{K} e^{-at} \sin(kt+\Phi)\right] - \frac{1}{M_r \omega_0^2}, \quad (3)$$

where

$$k^2 = \omega_0^2 - a^2; \operatorname{tg} \Phi = \frac{k}{a}.$$

This relation is represented graphically in Fig. 2. The dynamic errors due to a sudden application of the variable under test are shown by hatching in the graph.

In designing the transducer it is necessary to know its transient time $t_{tr}$ i.e., the time required for the transition curve to enter the zone of the tolerance $\Delta\delta_t$.

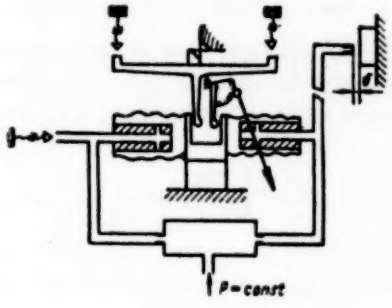



Fig. 1

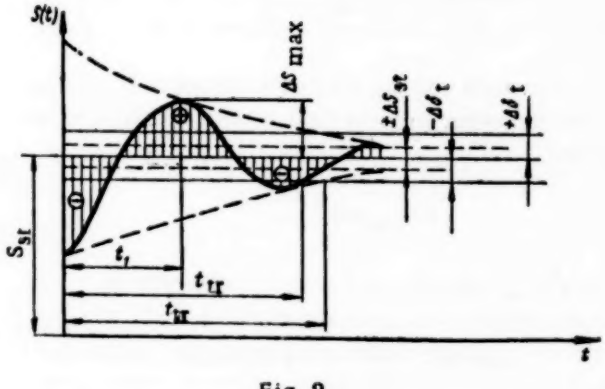



Fig. 2

Analyzing the transient period can be done in the following manner. Let us substitute the given tolerance $\Delta\delta_t$ in (3) instead of $\Delta S_1(t)$, and multiply the right-hand side of of the equation by the actual value of the pressure $\Delta p = \Delta p \pm \delta p_{st}$, in order to obtain the actual error of the transducer with respect to $\Delta p$, and let us consider that $\sin(\omega t + \phi)$ always equals minus one, then we obtain:

$$\Delta\delta_t = \frac{\Delta p}{M_r \omega_0 k} e^{-at_{tr}}.$$

From the above it is possible to determine:

$$t_{tr} = \frac{1}{a}[\lg \Delta p - (\lg \Delta\delta_t + \lg M_r + \lg \omega_0 + \lg k)]. \quad (4)$$

It will be seen from the above formula that the transient period depends on the value of the referred mass error effect, the stiffness of the elastic elements and the dynamic resistance of gas.

It is very simple to find graphically the transition period of a transducer. Let us draw a straight line parallel to the static characteristic, at a distance equal to $\Delta\delta_t$ below and above the static characteristic up to its crossing with the envelope curves determined by the formula:

$$p = \pm \frac{\Delta p}{M_r \omega_0 k} e^{-at}.$$

Let us drop a perpendicular from the point of intersection to the t-axis. The values of time thus obtained on the t-axis are the required transient periods $t_{tr}$.

In designing the device the following condition must be observed:

$$t_{op} < t_{tr} \quad (5)$$

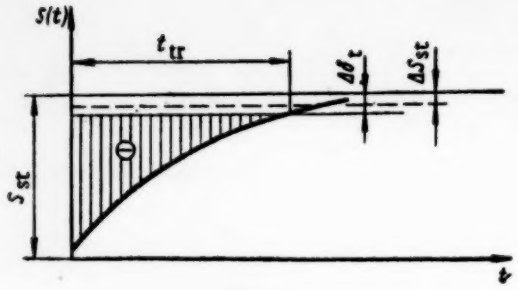



Fig. 3

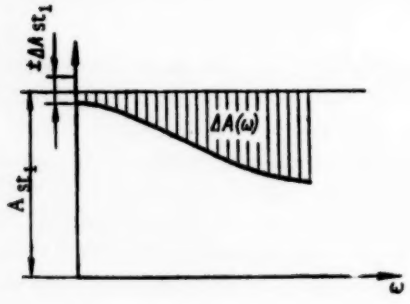
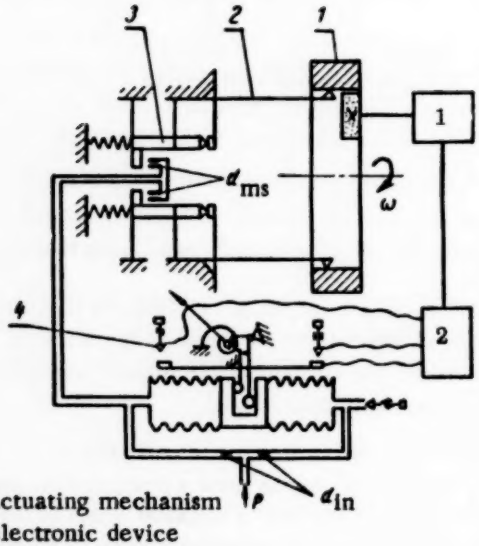



Fig. 4




1) actuating mechanism
2) electronic device

Fig. 5

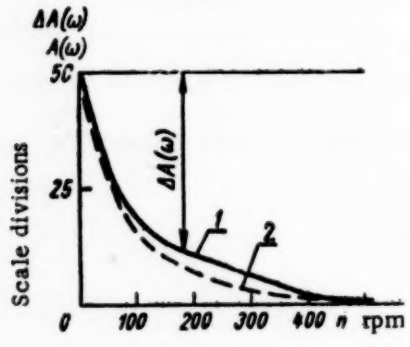



Fig. 6

where $t_{op}$ is the time interval from the instant the detail is set for measurement to the instant when the measurement recording relay operates.

If the $t_{tr}$ is given by a cyclogram, it is possible to establish the error of the transducer from the formula:

$$\Delta S(t_{tr}) = -\frac{\Delta p}{M_r\ \omega_0 k} e^{-at_{tr}} \sin(kt_{tr} + \Phi) \quad (6)$$

if the following condition is preserved:

$$\Delta S(t_{tr}) < \delta_t . \quad (7)$$

If according to calculations conditions (5) and (7) are not preserved it is necessary to change the parameters of the transducer in order to meet the requirements.

The maximum dynamic error of the transducer for a sudden application of the variable under test is obtained from the maximum value of function (3), i.e., when

$$t_1 = \frac{1}{k}\left(\frac{3\pi}{2} - \Phi\right).$$

By substituting $t_1$, we obtain

$$\Delta S_{max} = \frac{\Delta p}{M_r\ \omega_0 k} e^{-a\left(\frac{3\pi}{2} - \Phi\right)}.$$

For a constant voltage across the circuit it is necessary to meet the following, required for a correct operation of the transducer:

$$\Delta S_{max} < \Delta S_t .$$

For $a^2 = \omega_0^2$ the transient error function will be

$$\Delta S(t) = -\frac{\Delta p}{M_r\ \omega_0^2} e^{-at}(1 + at). \quad (8)$$

Graphically this is shown in Fig. 3. The transient process has now become aperiodic.

Tests have shown that for certain pneumatic transducers an aperiodic transient process is observed when the whole system of the transducer, the tubing and throttles is taken into consideration.

Amplitude-frequency accuracy characteristic of the transducer:

$$\Delta A(\omega)_1 = A_1(\omega) - A_{st_1} \pm A_{rd_1} = |F(j\omega)_1| - A_{st} \pm \Delta A_{rd_1} =$$
$$= |(k - M_r\ \omega^2)^2 + D^2\omega^2|^{-\frac{1}{2}} - A_{st_1} \pm \Delta A_{rd_1} \quad (9)$$

where $\Delta A_{rd_1}$ is the random portion of the transducer error which is equal to $\Delta A_{st_1}$ for $\omega = 0$.

The hatched portion of the graph in Fig. 4 represents this characteristic.

The static amplitude can be obtained from the amplitude-frequency characteristic for $\omega = 0$, then:

$$A_{st_1} = A_1(\omega = 0) = \frac{1}{M_r \omega_0^2} \pm \Delta A_{st_1} = \frac{1}{k} \pm \Delta A_{st_1} .$$

For $\omega = \omega_0$ we obtain a resonance and for higher values of a the curve flattens out.

In order to obtain normal operation of the transducer it is necessary to preserve the condition:

$$\Delta A < \Delta\delta_t . \tag{10}$$

If required, it is possible to determine the maximum tolerance frequency of the detail movement from the given tolerance measurement error, by substituting $\Delta\delta_t$ in (9).

After transformation we shall then obtain:

$$\omega_{1,2} = \sqrt{\frac{1}{2}\left\{-(4a - 2\omega_0^2) \pm \sqrt{(4a - 2\omega_0^2)^2 - 4\left[\omega_0^4 - \frac{1}{M_r^2\left(\frac{\Delta\delta_t}{A_0} + A_{st_1}\right)^2}\right]}\right\}} \tag{11}$$

The smaller of these parts is the tolerance. This is represented graphically in Fig. 4.

When the device consists of several elements, it is necessary to write separately all the equations and find the general characteristic of the system from the corresponding types of connecting portions.

For instance, for a contactless pneumatic controlling device, which consists of the transducer proper, pneumatic tubing and throttles, and is used in grinding, the amplitude-frequency accuracy characteristic will have the following form in the case when the term of the third derivative is not taken into account, owing to its small effect on the transducer's operation in the working range:

$$\Delta A_1(\omega) = [1 - (B_1\omega - B_2\omega^2)^{\frac{1}{2}}] \frac{1}{\sqrt{1 + D_1\omega^2}} \times \frac{1}{\sqrt{(k - M_r\omega^2)^2 + D^2\omega^2}} - A_{st_1} \pm \Delta A_{rd_1}, \tag{12}$$

where $B_1$, $B_2$ are the coefficients which depend on the operating conditions, and parameters of the tubing, and are small, hence in computations which do not require great accuracy they can be neglected; $D_1$ is a cofficient which depends on the operating conditions and the parameters of the pneumatic system.

Computations of an actual pneumatic device by means of equation (12) showed that for a given operating condition the characteristic curve has no resonance peak and decreases gradually with rising frequency as shown in Fig. 4.

Thus a thermometric study confirmed the possibility of using an automatic control method for analyzing systems of automatic checking of dimensions in engineering.

In order to confirm the results of the theoretical studies, experimental work was carried out in determing the dynamic accuracy characteristics and differential equation coefficients for systems of automatic checking of dimensions, and a special equipment was built by the author for simulating various conditions of the checking process [3].

Dynamic accuracy characteristics of a device for controlling internal grinding of holes with tolerances of 0.04 mm were obtained and tested out on this equipment. A differential bellows transducer was used as a sensitive element (Fig. 5).

The controlled detail 1 rotates as it is being machined. The measured dimension is transmitted through lever mechanism 2 to the spring suspension arms 3 thus varying the gap in front of the throttle $d_{ms}$. A bellows transducer registers this variation and as soon as the set limits are attained, the electrical contacts 4 send a pulse to the actuating device which switches the operation from rough to finishing grinding, stops feeding the detail and switches off the machine. The permissible run-out did not exceed the diameter tolerances, i.e., the maximum run-out did not exceed 40 $\mu$. The ground detail rotated at a speed of 90 rpm. The operating pressure was P = 1.5 kg-wt/cm$^2$, $d_{in} = 0.7$ mm, $d_{ms} = 2$ mm, the internal diameter of tubing was 4 mm, and its length about 1 m.

In order to determine the dynamic error quantitatively, we measured a series of amplitude-frequency accuracy characteristics (Fig. 6).

It will be seen from Fig. 6 that the dynamic error of this control device amounts to 15 $\mu$.

In order to reduce this error to the tolerances specified for this operation which are 7-8 $\mu$, we used (12).

Assuming $B_1$ and $B_2$ equal to zero owing to their smallness, we have from (12)

$$\Delta A_1(\omega) = \frac{1}{\sqrt{1+D_1\omega^2}} \times \frac{1}{\sqrt{(k-M_r\omega^2)^2+D^2\omega^2}} - A_{st_1} \pm \Delta A_{rd_1} \tag{13}$$

or in a general form:

$$\Delta A_1(\omega) = \frac{1}{\sqrt{T_1^2\omega^2+1}} \times \frac{R}{\sqrt{(1-T_2^2\omega^2)^2+4\xi^2T_2^2\omega^2}} - A_{st_1} \pm \Delta A_{rd_1} \tag{14}$$

where

$$T_1 = \sqrt{D}; \quad T_2 = \sqrt{\frac{M_r}{k}}; \quad R = \frac{1}{k}; \quad \xi = \frac{a^2}{T_2^2}.$$

It follows from (14) that in order to improve the above characteristic it is necessary to eliminate all junctions, curves, turns or any other local aerodynamic resistances in the pneumatic tubing system; increase the diameter of the input throttles (local resistance) within the limits of sufficient sensitivity; decrease the consumption of air; lower the operating pressure; reduce the initial gap within the limits of the linearity of the static characteristic; reduce the volume of the connecting system and the bellows chamber (or the chamber of the diaphragm transducer); decrease the referred mass of the moving part of the system; and raise the stiffness of the elastic system.

All these measures amount to decreasing the values of $T_1$, $T_2$ and $\xi$.

Guided by these relations among the coefficients and parameters of the control system, we can vary the parameters according to the theoretical conclusions, in order to obtain the best dynamic accuracy characteristics.

With a given transducer and a given construction of the controlling device, we attained by possible variations of the parameters in the permissible limits of sensitivity a reduction of the dynamic error for the diameter of the detail to the tolerance value of 6-7 $\mu$.

For a further reduction of the dynamic error it is necessary to change the construction or the type of transducer, guided by the properties of the differential equations of the system.

Another possibility of decreasing the dynamic error consists in dynamic adjustment of the system which

amounts to adjusting the transducer in the course of operation instead of doing it statically, thus taking into account the systematic dynamic error characteristic for definite conditions of operation. For instance, in our concrete case it would be necessary to adjust the transducer for the dimension of $D+2A_{st} - 2\Delta A(\omega_p)$ at the high limit instead of dimension $D+2A_{st}$ for a two-contact measurement, where D is the transducer's reading which corresponds to the minimum diameter at the end of machining; $2A_{st}$ is the reading of the transducer which corresponds to ovalness of the detail, i.e., $D_{max}$-D; $2\Delta A(\omega_p)$ is the double dynamic error of the amplitude at the working frequency of $\omega_p$.

In the case of dynamic adjustment, the measurement error cannot be completely excluded. A certain error remains which is of a random nature and differs at different frequencies.

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# AN AUTOMATIC ELECTRONIC COORDINATE MEASURING EQUIPMENT FOR A HEAVY BORING MACHINE


E.L. Abramzon, G.L. Grin, A.Ya. Peliks, and S.S. Podlazov



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When large pieces are being bored on heavy lathes, it takes a long time to measure the displacement of the mandrel with respect to the table carrying the piece. It is difficult to make these measurements because the place of work where the elements controlling the lathe are mounted is far away from the measuring equipment. It is especially difficult to produce accurate work when one workman watches the scale of the measuring instrument and the other controls the machine.

The rapid development of heavy engineering and the required rise in the accuracy of machining make it necessary to establish a more accurate method of measuring displacements of tools covering a wider range (5-10 m), and the possibility of remote measurements by means of devices placed near the control elements of the lathe.

A special design office of the Moscow City Council of National Economy developed an equipment for measuring displacement coordinates, both vertical and horizontal, of a heavy boring machine, by means of two circular inductive transducers and a reversible electronic counter which operates with decatrons.

One of the transducers is fixed to the headstock of the machine. A roller, 133.690 mm in diameter, is placed over the body of the transducer and pressed against a rack which is fixed parallel to the direction of movement of the headstock along the vertical pillar of the machine.

When the headstock is displaced vertically along the pillar, the roller together with the body of the transducer rotates with respect to the transducer axle, thus transforming the linear displacement into a rotary motion of the transducer moving element without any slipping.

* See English translation.

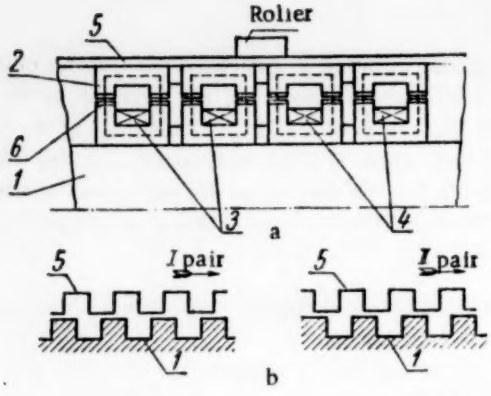


Fig. 1. Longitudinal (a) and transverse (b) cross sections of the induction transducer (the stationary portion of the transducer is shaded).

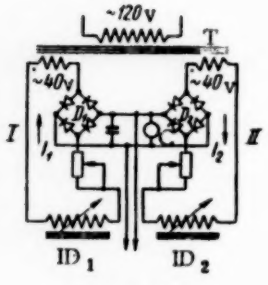


Fig. 2.

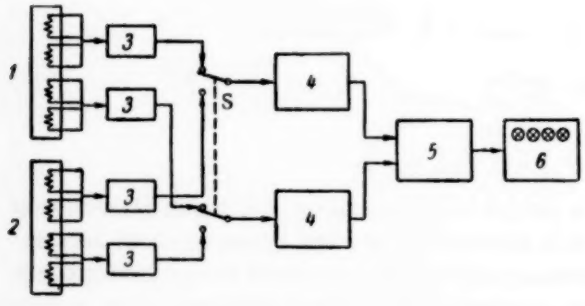


Fig. 3.

The second transducer is fixed to the pillar and its roller is in contact with a rack placed along the base of the machine parallel to the horizontal displacement of the pillar together with the headstock along the base.

Axle 1 (Fig. 1) of the transducer carries four geared rings 2 with z teeth on each external rim (for this model z = 420). The basic 3 and auxiliary windings are wound in the recesses of the rings. Body 5 of the transducer carries four gear rings 6 with the same number of internal teeth. The gap between the internal and external teeth amounts to 0.1 mm. The rings are mounted in the body in such a manner that the teeth of the second ring are staggered with respect to those of the first by half a pitch. The magnetic circuits of the coils are independent of each other (dotted line in Fig. 1).

The variation in the relative position of the external and internal teeth, due to the rotation of the body of the transducer, produce periodic variations of the magnetic flux in the coils of the transducer.

The basic coils $ID_1$ and $ID_2$ (pairs I and II of the ring) are connected to a differential circuit (Fig. 2), which is fed from tranformer T. The currents flowing in circuits I and II are rectified in the bridges $D_1$ and $D_2$ consisting of four germanium diodes each.

The balancing circuit and pointer of indicating instrument G are at zero when the currents in circuits I and II are equal. This corresponds to the relative position of rings I and II shown in Fig. 1. When the body of the transducer leaves the balanced position, the teeth of moving ring pair I approach those of the stationary ring. The teeth of the moving ring pair II recede from those of the stationary ring; at the same time the magnetic flux and the impedance of pair I coil increase whereas those of pair II coil decrease, thus producing a decreased current in circuit I and an increased one in circuit II, and making the indicator pointer deflect from the zero position.

The sensitivity of the circuit with the above parameters is such that the deflection of the indicator pointer by 5 μa from its zero position corresponds to a linear displacement of 3 μ or an angular rotation of 9°.

After the passing of each half-pitch the currents will equalize and the indicator will again point to zero. The diameter of the roller is chosen to make the zero positions correspond to 0.5 mm displacement of the transducer along the rack.

The output signal which consists of a sinusoidal function of displacement is transmitted to the input of the electronic counter, which counts displacement in millimeters. The frequency of the signal has a linear relation to the speed of the transducer displacement along the rack.

In order to determine the direction of the movement of the transducer it contains an auxiliary pair of rings III and IV. These rings are staggered in the body of the transducer with respect to the basic rings by one-quarter of a pitch, respectively. Their coils are connected to a differential circuit similar to the one described

above. However, the output signal of the second circuit is displaced by ± 90° with respect to the signal of the first circuit, depending on the direction of the movement.

The displacement to a given value is attained in the following manner. In the initial position of the carriage the readings of the counter are reset to zero and the indicator reading is set to zero by turning the transducer axle. The required value is set on the vernier scale of the micrometer device, which reads in fractions of a millimeter, and the machine is displaced until the counter reads the required whole number of millimeters and the pointer of the indicator is set to zero.

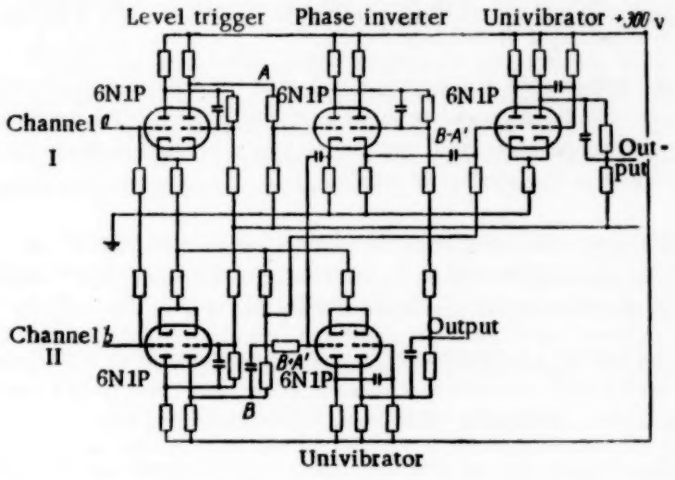


Fig. 4.

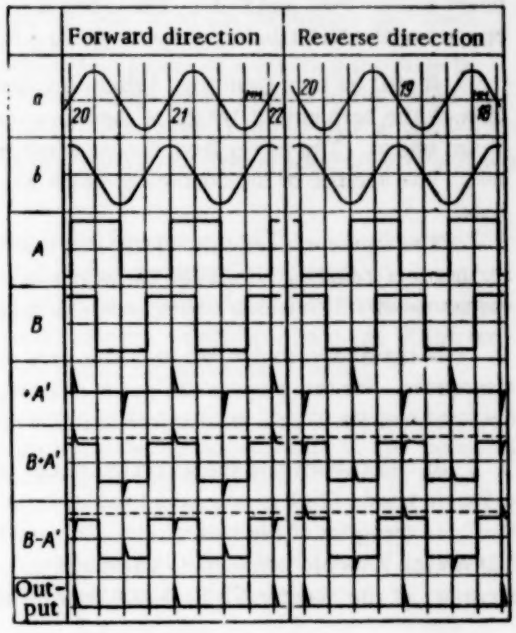


Fig. 5.

The block schematic of the equipment is shown in Fig. 3. Two transducers 1 and 2 are connected in pairs to the differential circuit 3, transducer 1 is intended for measuring the horizontal displacement and 2 for the vertical displacement of the cutting tool. Switch S connects the electronic part of the equipment to one of the transducers depending on the operation being carried out on the machine. The output signals of the differential circuit are amplified by a dc amplifier 4 and fed to unit 5 for determining the direction of the movement. The reading of the whole number of units is taken from the counter which consists of decatrons (counting unit 6). The equipment is fed from a power pack containing an electronic and ferroresonance stabilization. In order to improve the shape of the output signals of the differential circuits, their outputs are connected to bridge RC type filters which suppress ripple after full-wave rectification. The filters include the facility of controlling the quasi-resonance frequency.

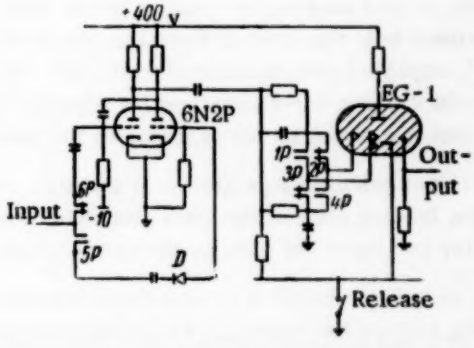


Fig. 6. Schematic of a counting unit. Relay contacts P1-P6 are shown in the position for a forward movement (addition).

In the unit which determines the direction of the movement by means of two transducer signals displaced with respect to each other by 90° (Figs. 4 and 5), the sinusoidal signals a and b are transformed first by the shaping circuit, which consists of the level trigger using the 6N1P triode, into corresponding rectangular signals A and B (Fig. 5) which change their sign at the point when the signal passes through zero.

The left-hand side of Fig. 5 shows the nominal phase relations for a uniform movement in the forward direction and the right-hand side of the diagram, the movement in the reversed direction. It will be seen from

the diagram that in the first instance the sinusoidal signal a of one of the channels lags in phase by 90° the second channel signal b. When the object moves in the opposite direction signal a leads signal b by 90°.

Since for an accurate computation one signal is sufficient and the second signal is only used for determining the direction of the movement, it is possible to allow a deviation of ± 25° from the theoretical phase difference of 90°.

After transformation, the rectangular signal A of the first channel is reversed in phase by triode 6N1P. Signals +A and -A are differentiated by the RC network. Thus at different points of the electrical circuit there are differentiated signals +A' and -A'. These signals are added to signal B of the second channel and form combined signals B+A' and B-A'. The latter are fed to the appropriate grids of the univibrator stages, which also operate with 6N1P triodes, whose triggering level is shown by a dotted line in Fig. 5.

It will be seen from Fig. 5 that only one of the univibrators can be triggered when the signal passes from a through the zero point. Which of the two univibrators will be triggered depends on the direction of the movement of the object. The pulses from the univibrators are fed to the electronic count reversing relay and to the counting unit. The number of the counted pulses is exactly equal to the number of pitches passed by the inductive transducer.

The electronic circuit of the unit which determines the direction of the movement does not affect the accuracy of counting, since the variations of the threshold trigger voltage do not exceed ± 0.1 v for line voltage variations of ± 10%, which corresponds to a transducer displacement of the order of fractions of a micron.

In the above equipment provisions are made for setting up coordinates in the counting unit with a stationary transducer. For this purpose the pulse generator is used which provides four fixed frequences of 1000, 100, 10, and 1 cps, and consists of an asymmetrical multivibrator using a double triode 6N1P, which is triggered by hand.

In order to reverse the direction of the counter, a trigger circuit with two stable positions and consisting of a double triode 6N1P is connected to the input of the unit. The circuit is sensitive to positive pulses fed separately to the grids of the two triodes. In parallel with the anode loading of one of the triodes, two electromagnetic relays type RKN are connected, whose contacts (1P-6P in Fig. 6) produce the required switching in the counting elements of the computer unit, when forward or reverse counting is required (Fig. 6).

The counting unit comprises a four-decade circuit consisting of EG-1 (10SG-1B) decatrons triggered by pulses from the RC network of the pulse splitting circuit; the first pulse is fed to the first set of guides and the second one to the second set when a forward movement is recorded (addition). When the movement is reversed (subtraction) the first pulse is fed to the second set of guides and the second one to the first set. The reading is indicated by the position of the light spot against numbers engraved on the scale ring. When the movement is in the forward direction, the pulses are fed from the reversing unit to the left-half of double triode 6N1P, amplified and transmitted to the RC network of the decatrons. The output pulse of a decatron amounts to 10-20 v which is not sufficient for tripping the next decatron. Hence the pulse is fed from the output of the decatron, i.e., from its zero cathode to the amplifying tube of the next counting element, etc.

When the discharge glow is at the zero cathode, a positive pulse appears at the output of the decatron and the leading edge of this pulse coincides with the instant the glow arrives at the cathode and its trailing edge with the passing of the glow to the next cathode.

In order to ensure a correct count, irrespective of the direction of counting (addition or subtraction), the leading edge of the pulse is used for addition (positive pulse) and its trailing edge for subtraction (negative pulse). This is necessary since the change of a number in a higher order element occurs in addition, when the number in the adjacent element of a lower order passes from 9 to 0 (249 → 250) and in subtraction, from 0 to 9 (250 → →249), which corresponds to a positive output pulse of a decatron for addition and a negative pulse for subtraction.

In addition the positive input pulse is fed to the grid of the left-hand side triode 6N1P, which is blocked by a negative bias, it is amplified and transmitted to the RC network of the decatrons. A negative pulse has no effect on the circuit.

In subtraction, the negative input pulse is fed to the grid of the right-hand side triode 6N1P, is inverted in phase, and amplified by the left half of the triode and transmitted to the RC network of the decatrons. Positive pulses are rejected by the diode D.

The supply circuit is stabilized by means of two electron and one ferroresonance stabilizers. The whole equipment includes 30 electron and gas discharge tubes and 25 germanium diodes.

The electrical circuit of the equipment is mounted on a desk(330 x 215 x 230 mm)and in a cabinet (730× ×1100×300 mm).

All the electronic units of the equipment were checked experimentally and proved to be completely reliable in the range of transducer input frequencies of 50-500 cps.

The basic components of the errors in determining the coordinates of a displacement consist in the errors of the inductive transducer proper, namely the errors due to the deviations in the diameter of the roller, which runs over the rack, eccentricity of the roller, and errors in the angular graduation of the transducer gear rings.

The errors of an inductive transducer with a roller were determined by means of a dividing machine in comparing the readings of the transducer with those of the optical scale. Those errors referred to the linear displacement of the transducer amount to ~ 15 $\mu$. The error in calibrating the transducer in this case amounted to ~1 $\mu$. The remaining errors due to the electrical circuit are negligibly small as compared with the errors of the inductive transducer.

The maximum speed of displacement of the above inductive transducer amounts to 0.5 m/min when fed from commercial frequency mains. If it is required to raise the speed of its movement it becomes necessary to feed the transducer with voltages of a higher frequency. According to the tests carried out the supply frequency should be four times higher than than the maximum pulse repetition frequency. Otherwise,the shape of the output signal of the differentiating circuit becomes greatly distorted thus producing incorrect counting.

It should be remembered that in raising the frequency of the supply voltage of the inductive transducer with a continuous core, the sensitivity of the transducer is lowered owing to the increased losses in the core and the magnetic skin effect. A transducer of the above design was checked at a supply current of 500 cps which corresponds to a speed of linear displacement of 7.5 m/min.

The use of the above circuit for an automatic and accurate stopping of the object is of interest. The number which corresponds to the required displacement is first set on the counter. With the movement the counter subtracts digits down to zero. At the same time the machine is automatically switched over to a lower speed and finally stopped with great precision.

## CHECKING THE CURVATURE OF THREAD GAUGES

F.P. Frolov

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July, 1960

The reasons for the bad fitting of thread gauges in the manufactured details are given in [1] and it is suggested that the deviations of the helix angle from its nominal value should be checked, i.e., that the curvature of the thread should be checked. For this purpose it is recommended in [1] that a special instrument developed in the Interchangeability Bureau be used.

We completely agree with the above conclusions and suggestions, including the suggestion of specifying in the standards, regulations and technical requirements the curvature of the thread by gauges; but we,consider it useful to bring to the notice of the readers of this journal the experience gained by the "Krasnaya Étna" plant where the curvature of the thread was successfully checked on suggestion by G.I. Molodtsev,the head of the Central Test Laboratory,before the special instrument proposed in [1] was made.

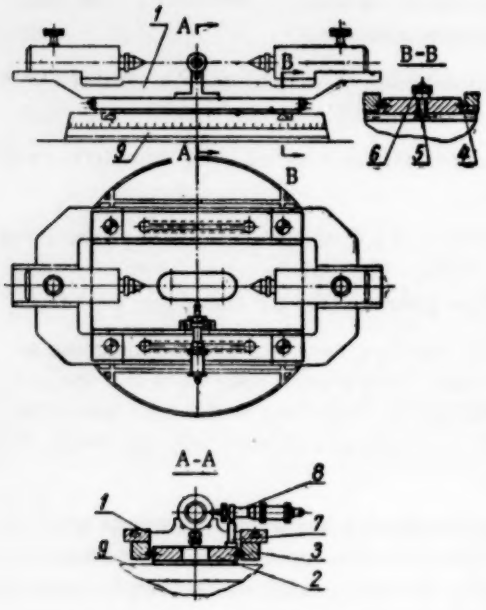


Fig. 1

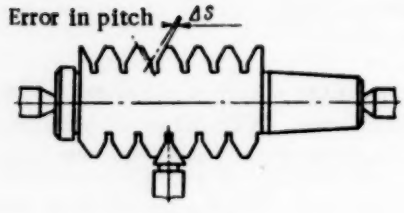


Fig. 2

The measurement of the deviation of the helix angle along the thread in thread gauges and taps was carried out at the "Krasnaya Etna" plant according to the above mentioned suggestion, by means of a projection method of an instrument microscope with an error of 3 μ referred as a mean diameter, which provides good fit of manufactured details with tight and small grade 1 threads.

For this purpose the microscope is supplied with a specially made attachment (Fig. 1) for the central frame 1 which provides a free travel of the frame along its guides.

The attachment consists of a middle strip 2 and side strips 3 which can be smoothly displaced on balls along V-shaped guides. Strips 3 are firmly fixed to frame 1, by means of the holes existing in the frame. The middle strip 2 is fixed to the microscope stage by means of two screws 5 and nuts 6 (the screws and nuts intended for fixing frame 1 to stage 9 of the microscope are used). The stationary strip 2 carries stand 7 which is firmly fixed to it and has in its upper part a groove of 6 × 10 mm and two 3 mm holes. A thread micrometer 8 with its frame cut-off is fixed in the groove at the level of the centers by means of two pins.

The gauge under test (Fig. 2) is fixed in the centers, the insert of the thread micrometer is placed in the fillet of the gauge screw and the profile of the opposite of the gauge is placed under the cross hairs of the microscope head by displacing the microscope stage. Next the gauge is smoothly turned observing at the same time the projection of the microscope head cross-hairs; if the hairs remain inside the profile of the thread along the entire length of the thread, the helix angle of the thread is correct; if the projection of the hairs comes periodically outside the profile of the thread, the helix angle is defective along the length of the thread, the thread pitch changes and hence this gauge will have a bad fit with the produced article. These errors can be compensated by decreasing the mean nominal diameter of the gauge or by increasing it for the thread of the detail. The computation formulas for this purpose are cited in [1].

Before the manufacture of the special instrument, it is recommended to adapt the measuring microscope for checking the errors of the helix angle along the length of the thread by making the above special attachment.

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*See English translation.

# COMPUTING THE DISPLACEMENT OF THE INITIAL CONTOUR OF GEARS WHEN THEY ARE CHECKED BY MEANS OF BALLS

P.M. Danilyuk

Translated from Izmeritel'naya Tekhnika 1960, No. 7, pp. 25-26,
July, 1960

The computing method here described provides a direct evaluation of the displacement of the initial contour of spur gears when they are being checked by means of balls.

The method also provides the possibility of determining the value of the radius vector of the point of contact of the ball with the side profile of the tooth space.

Let us first examine the case of checking a spur gear with an even number of teeth. Let us insert two balls of an equal diameter d into diametrically opposite tooth spaces of the gear. Let us denote by $M_e$ the distance between the extreme points of the balls (Fig. 1a). Then the distance from the center of the ball to the axis of the wheel will be:

$$OC + 0.5\,(M_e - d). \tag{1}$$

Let us draw through the center of the ball a line AC (Fig. 2) which is tangential to the basic circumference of the gear and let us connect point A with the center of the gear. Let us now determine angle $\zeta_x$ between the radius OA and the bisector of the tooth space. We have:

$$\operatorname{tg} \zeta_x = \frac{AC}{r_o}, \tag{2}$$

where $r_o$ is the radius of the basic circumference.

The length of the tangent AC can be determined from the triangle OAC:

$$AC = \sqrt{[0.5\,(M_e - d)]^2 - r_o^2}. \tag{3}$$

The radius of the basic circumference is equal to:

$$r_o = 0.5 mz \cos \alpha_\partial, \tag{4}$$

where m is the module; z is the number of the teeth of the wheel; $\alpha_\partial$ is the generating angle for the point on the involute which coincides with the pitch circle of the gear.

By substituting in (2) the values obtained from (3) and (4) we have after transformation:

$$\operatorname{tg} \zeta_x = \sqrt{\left(\frac{M_e - d}{mz \cos \alpha_\partial}\right)^2 - 1}. \tag{5}$$

From the above we can find the value of angle $\zeta_x$ for checking a gear with an even number of teeth:

$$\zeta_x = \operatorname{tg}^{-1} \sqrt{\left(\frac{M_e - d}{mz \cos \alpha_\partial}\right)^2 - 1}. \tag{6}$$

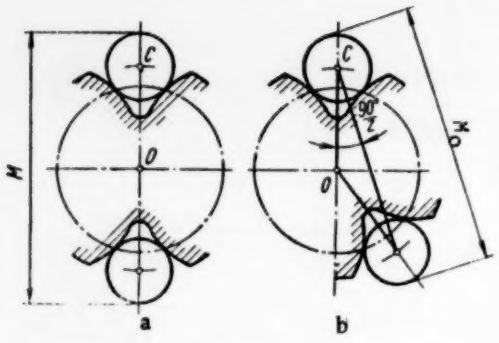


Fig. 1. Position of two balls in checking a spur gear: a) with an even number of teeth, b) with an odd number of teeth.

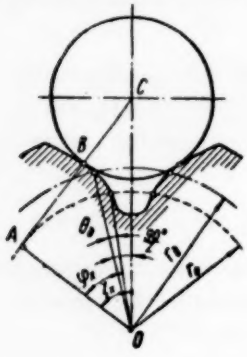


Fig. 2. Position of a ball in a tooth space in a general case.

By denoting the distance between the extreme points of two balls placed into the opposite tooth spaces in a gear with an odd number of teeth by $M_0$ (Fig. 1b), we can obtain in a similar manner a formula for determining the value of $\tan\zeta_x$ and $\zeta_x$ for this type of control.

$$\operatorname{tg}\zeta_x = \sqrt{\left(\frac{M_0 - d}{mz\cos\alpha_\partial \cos\frac{90^\circ}{z}}\right)^2 - 1} \qquad (7)$$

and

$$\zeta_x = \operatorname{tg}^{-1}\sqrt{\left(\frac{M_0 - d}{mz\cos\alpha_\partial \cos\frac{90^\circ}{z}}\right)^2 - 1} \qquad (8)$$

If the gear wheel is cut with a certain displacement of the initial contour $\Delta h = m\xi$, angle $\zeta_x$ can also be expressed in the following manner (Fig. 2):

$$\zeta_x = \varphi_x + \frac{90^\circ}{z}\left(1 - \frac{4\xi \operatorname{tg}\alpha_\partial}{\pi}\right) - \theta_\partial, \qquad (9)$$

where $\varphi_x$ is the involute angle at the point where the ball touches the involute; $\xi$ - the coefficient of displacement of the initial contour; $\Theta\partial$ - the involute angle for the point where the involute coincides with the pitch circle.

The involute angle $\varphi_x$ is equal to:

$$\varphi_x = \frac{AC - 0{,}5d}{r_0}. \qquad (10)$$

From the above and taking into consideration (3), (4) and (5) we obtain for gears both with an odd or even number of teeth:

$$\varphi_x = \operatorname{tg}\zeta_x - \frac{d}{mz\cos\alpha_\partial}. \qquad (11)$$

By substituting (11) in (9) and making the required transformations, we obtain for the coefficient of displacement of the initial contour the following expression:

$$\xi = 0{,}5z\cot\alpha_\partial\left(\frac{\pi}{2z} + \operatorname{tg}\zeta_x - \zeta_x - \theta_\partial\right) - \frac{d}{mz\cos\alpha_\partial}. \qquad (12)$$

Here, depending on the number of teeth in the wheel under consideration, the values of $\tan\zeta_x$ or $\zeta_x$ are taken respectively from (5) and (6) or from (7) and (8).

For determing the actual displacement $\Delta h$ of the initial contour it is necessary to multiply the value $\xi$ thus obtained by the module.

Let us now determine the value of the radius vector $r_x$ at the points of contact between the ball and the side profiles of the tooth space. It is necessary to determine the radius vector $r_x$ in checking the displacement of the initial contour in order to find whether the points of contact lie on the involute part of the profile when the point of the tooth is flanked. It will be seen from Fig. 2 that the length of the tangent AC is equal to:

$$AC=\sqrt{r_x^2-r_o^2}+0.5d. \tag{13}$$

By equating (13) and (3) and taking (4) and (5) into consideration, we obtain after transformations an expression for the radius-vector used in checking wheels both with an even and odd number of teeth:

$$r_x=0.5mz\cos\alpha_\partial\sqrt{\left(\operatorname{tg}\zeta_x-\frac{d}{mz\cos\alpha_\partial}\right)^2+1}, \tag{14}$$

where the value of $\tan\zeta_x$ should be taken from (5) or (7).

For the above computations involute function tables are not required.

## CHECKING THE SLOPE ANGLE OF HELICAL GEAR TEETH

V.N. Levitskii

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 26-27,
July, 1960

The simplest and easiest method of controlling the slope angle and direction of teeth as well as the rectilinearity of the contact line consists in staining the teeth and working the wheel with a coupled measuring gear, as carried out on the KPD-300 instrument of the "Kalibr" plant or the MIZ instrument. This method, however, does not provide an indication of the real value of the error. Instruments for checking the direction and the slope angle of teeth and the rectilinearity of the contact line over the base cylinder are made in restricted numbers owing to their complicated design and heavy cost. These are the reasons which prompted the "Vulkan" plant to use a method of checking the direction and slope angle of teeth and the rectilinearity of the contact line by means of the large measuring microscope type BMI.

The helical wheel under test is fitted on a mandrel fixed in the centers. The base with the centers and the mandrel which carries the wheel are fixed by means of pins in the groove of the round stage and secured with screws. Next, the round stage which carries the centers is turned about its axis and is provisionally set at the angle of slope of the tooth to be tested. The extensometer lever, which is fixed to the tube of the microscope by means of a clamp, is lowered until its tip touches the tooth at the contact line and then the extensometer is loaded (1-2 turns of the pointer).

In order to determine the rectilinearity of the contact line and the actual slope angle of the tooth, the round stage is rotated and displaced along the axis in such a manner that the extensometer keeps the same reading during the entire displacement along the line of the tooth. This position of the extensometer corresponds to the contact line of the wheel along the axis of the microscope stage displacement, and the angular displacement of the stage indicates the angle of slope of the tooth along the base cylinder, as read off the round dial and the vernier scale of the BMI microscope with an error up to 3'. The rectilinearity of the contact line is determined by the extensometer reading with an error of 0.01 mm.

Conclusions. The above method of checking has provided the plant, which has no special instruments for this purpose, with the means of discovering and elminating large errors which arise during the setting or resetting of machines, and also provided it with a better control of the cutting tools by their geometrical parameters thus greatly improving the machining quality of helical gears.

# A KINEMATOMETER FOR SCREW-CUTTING LATHES

Yu.M. Andrushevich, M.K. Klebanov, M. Ya. Tslaf, and A. L. Rabhin

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July, 1960

The kinematometer we have developed is intended for measuring the degree to which the errors of separate elements of the screw-cutting lathe kinematic chain affect the accuracy of the thread.

The schematic of the experimental equipment is shown in Fig. 1. The screw-cutting chain of the lathe is checked by registering the relative displacement of support 1 and nut 2 of the standard certified screw 3 by means of a recorder type BV-662 with an inductive transducer 4. The nut cannot turn and the screw-cutting chain is adjusted to cut a thread with a pitch equal to that of the standard screw.

By following the pitch of the measured thread, we can produce a correspondingly certified nut and screw.

The construction of the nut with the transducer is shown in Fig. 2. The sectional nut is mounted in casing 1. The left-hand side of the nut is fixed to the casing, but the right-hand side can move with respect to it through an angle of 15-20° for the purpose of choosing the gap between the standard screw and the nut. After the gap has been selected this part of the nut is also secured to the casing by means of a screw.

Ring 2 is fitted with a gap onto the nut casing 1. The ring is centered with respect to the screw and the nut by means of setting pins 3. The ring is fixed by means of an adaptor to the cutter-holder and the support.

The housing 4 of the transducer is fitted onto the external cylindrical surface of the left-hand side part of the nut. The housing 4 is pressed against nut 6 which serves to adjust the gap in the transducer, by means of three screwed springs 5.

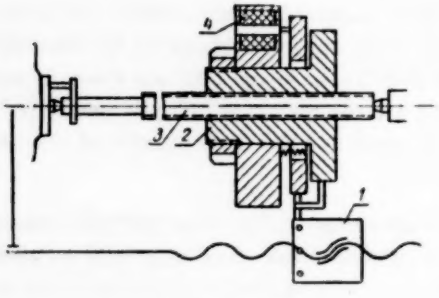


Fig. 1.

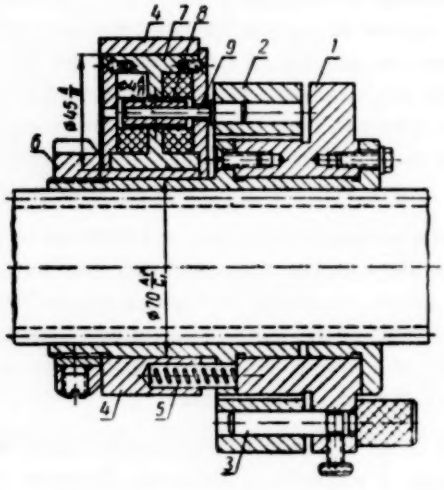


Fig. 2.

The induction transducer consists of three similar parts mounted in the borings of housing 4 at an angle of 120° to each other. Each part of the transducer consists of a cup 7, two coils of 1500 turns of PE-0.1 mm wire each, and an armature 8 fitted over a brass rod 9 fixed to ring 2.

After the nut with the transducer has been mounted on the standard screw the latter is fixed in the centers of the lathe and is connected by means of a lug to the mandrel, in such a manner as to avoid any relative turning of the mandrel with respect to the screw in a reversed direction.

If the screw-cutting chain of the machine is adjusted to the pitch of the standard screw, and the mechanism which rotates the mandrel is switched on, the standard nut together with the support and ring 2 in the adaptor will move longitudinally, since the nut is prevented from rotating. When there are no errors in the screw-cutting chain, the support and the standard nut are displaced at the same rate and the armature remains stationary with respect to the coil. When the chain has errors, the support together with ring 2 either lag behind or lead the movement of the standard nut and the elements attached to it. The armature 8 which is fixed to ring 2 is displaced

with respect to the coils and the gap between the end of the armature and the cover will decrease. The variation of the gap will lead to changes in the reluctance of the coils and hence in the voltage across it them.

The transducer is connected to an electric recorder type BV-662. The voltage-difference pulse fed to the recorder produces a displacement of its carriage with the pen. The deflections of the carriage are proportional to the relative displacement of the armature, and are recorded on a paper chart with millimeter calibrations. Since the displacement of the armature is equal to the relative displacement of the support and the standard nut, the recorded deflections on the chart are proportional to the error of the screw-cutting machine. In order to determine the actual errors, it is necessary to calibrate the transducer with the object of establishing the relation of the armature displacement to the deflections of the recording carriage.

By means of this kinematometer, experimental investigations were made of the effect of the elements of screw-cutting chains on the thread in a backing-off lathe 1811 and a screw-cutting and turning lathe 1A616P. The diagrams of the accumulated errors, recorded by means of this instrument, made it possible to put forward certain suggestions for decreasing the errors in the screw-cutting chains of these lathes.

# MECHANICAL MEASUREMENTS

## STRAIN-GAUGE ACCELERATION TRANSDUCERS

V.P. Neyukov, A.S. Zhmur, and G.L. Lyapin

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July, 1960

Strain-gauge transducers of two types,conventionally series A and series B were successfully used for measuring linear accleation.

The design of the series A transducers followed the pattern of the Leningrad Polytechnical Institute transducers. The transducers of the B series were made a little later when the defects of the earlier transducers could be taken into consideration.

Transducers of both types were made in several models of equal sensitivity.

The strain-gauge acceleration transducers of the A series (Fig. 1) used for their sensitive element two duralumin cups. The casing of the transducer consisted of a fairly rigid duralumin cylinder. The cups rest with their edges on the ends of the cylinder and their bottoms are connected by means of a coupling bolt, a nut and a lock nut. The total length of the two cups is smaller than that of the cylinder. This makes possible to provide an initial tension in the walls of cups when they are tightened by means of the bolt. The body with the required inertia consists of the bolt with the nut and the lock nut and the thick bottoms of the cups. The transducer is fixed to the instrument or the component under test by means of a sleeve nut.

The effect of acceleration on the transducer leads to the displacement of the body with the inertia with respect to the casing, and produces deformations of the cup walls.

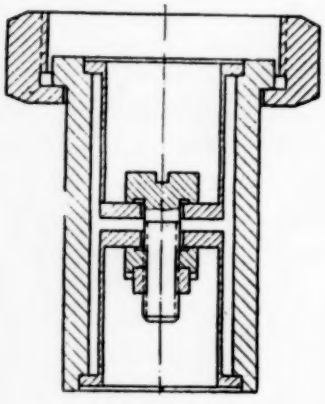

Fig. 1.

In order to convert the strains in the cup walls into electrical signals, two strain-gauge transducers are glued to the external surfaces of the cup walls. Each transducer of a pair glued to one cup is connected to the opposite arm of a bridge circuit. If the amplifier is designed to work with one-half of the bridge connected externally, only one transducer need be glued to each crop.

The use of duralumin for the manufacture of cups makes it possible to provide them with relatively thick walls, thus facilitating their machining and assembly.

Moreover with small displacements of the reluctant mass with respect to the casing, a material with a high damping coefficient is required and the high yield limit of duralumin makes it possible to set a sufficiently high initial stress without causing overloads at high accelerations.

In order to avoid the effect of the ambient temperature variations on the value of the initial stress, and hence on the sensitivity of the transducer, its casing and the coupling bolt with the nut must by made of the same materials as the sensing element.

In order to select a correct tension for the preliminary stressing, it is recommended to determine the mechanical properties of each consignment of the material used for making the basic elements of the transducer.

Preliminary stressing should not create in the walls of the sensing element stresses which exceed half the value of the elastic limit.

The value of the stress for transducers of the A series can be conveniently determined by means of the circuit shown in Fig. 2. When one of the operating elements of the transducer is stressed with a load equal to double the preliminary stressing, the reading of the galvanometer which is connected in the bridge diagonal is noted. Next the load is taken off and both the sensing elements are stressed by means of the specially provided spanners until the same reading of the galvanometer is obtained. The natural frequency of the transducer can only be determined experimentally.

TABLE 1

| Size type | Sensing element diameter d, mm | Length of sensing element working section $l$, mm | Thickness of the sensing element walls δ, mm | Weight of the reluctant body G, g-wt | Tightening force N, kg-wt | Limit of measurement in g units | Natural frequency f, cps |
|---|---|---|---|---|---|---|---|
| A-X-1 | 20 | 20 | 0.125 | 88 | 24 | 200 | 4000 |
| A-X-2 | 20 | 20 | 0.165 | 88 | 32 | 300 | 4600 |
| A-X-3 | 20 | 20 | 0.175 | 44 | 14 | 1000 | 6700 |
| A-X-4 | 20 | 20 | 0.185 | 44 | 47 | 1000 | 6900 |
| A-X-5 | 20 | 20 | 0.200 | 20 | 50 | 2000 | 10600 |
| A-X-6 | 20 | 20 | 0.400 | 22 | 80 | 4000 | 14900 |
| A-XII-1 | 15 | 15 | 0.07 | 26 | 8 | 250 | 5500 |
| A-XII-2 | 15 | 15 | 0.07 | 26 | 8 | 420 | 5500 |
| A-XIII-1 | 15 | 15 | 0.07 | 33 | 8 | 300 | 4900 |
| A-XIII-2 | 15 | 15 | 0.07 | 22 | 8 | 450 | 6000 |

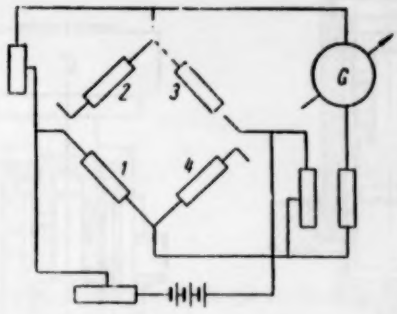

Fig. 2

If the required equipment is lacking, a tentative computation of the natural frequency of the transducer can be obtained from the formula:

$$f = \sqrt{\frac{d\delta E}{2\pi lm}},$$

where d is the mean diameter of the sensing element; δ the thickness of the sensing element walls; E is the elastic modulus of the material; $l$ the effective length of the sensing element; m is the mass of the reluctant body.

The basic data of the series A transducers is given in Table 1.

The main defects of the series A transducers consist in the complexity and incovenience of the stressing process.

Especially tedious work is required for the assembly of the transducer with thin-walled sensing elements. The friction force which arises between the bolt and cup, when the transducer is being tightened, may easily lead to the twisting of the cup walls. A transducer with a cup which is twisted even very slightly cannot be used, since the twisting disrupts the linear relation between the applied acceleration and the deformation of the sensing elements, thus making the balancing of the bridge difficult.

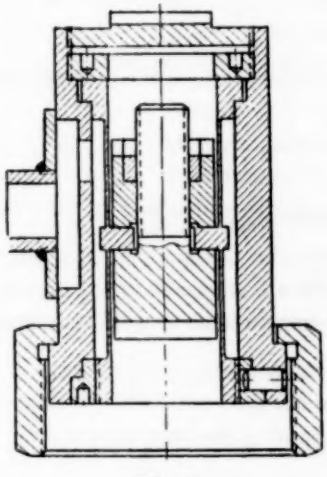
Fig. 3

Morever the series A transducers are to a certain extent sensitive to transverse vibrations.

Transducers of the B series have as a sensing element a solid duralumin cylinder.

The cylindrical casing contains the sensing element (Fig. 3) which consists of a thin-walled cylinder with thicker fixing rims and a diaphragm in its middle. The diaphragm is used for fixing the reluctant body which is also made in the form of a bolt with a nut and a lock nut. In this design the reluctant body does not affect in any way the stressing procedure, and can be fixed to the diaphragm at any stage of the assembly. With this design it is possible to change the sensitivity of the transducer by changing the reluctant body.

The upper portion of the casing has a nut which firmly holds one end of the sensing element after it is fixed in the casing. The upper end of the casing has a cap. The transducers are fixed to the elements under test by means of a sleeve nut.

For simplicity of assembly, a part of the sensing element which has an external thread is made longer than required from purely constructional considerations. In the stressing process an end piece is screwed onto this

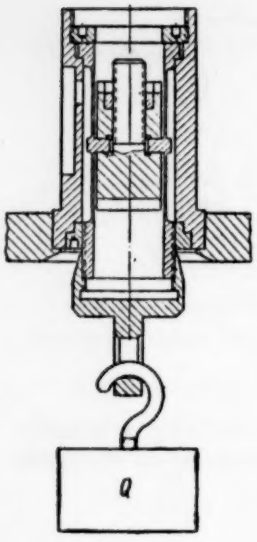


Fig. 4

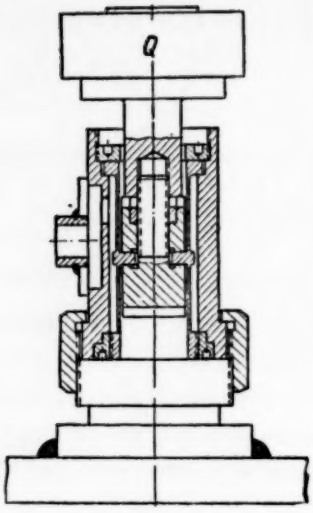


Fig. 5

TABLE 2

| Size type | Sensing element diameter d, mm | Length of sensing element working section $l$, mm | Thickness of sensing element walls $\delta$, mm | Weight of the reluctant body G, g-wt | Tightening force N, kg-wt | Limit of measurement in g units | Natural frequency $f$, cps |
|---|---|---|---|---|---|---|---|
| B-1 | 13 | 13 | 0.12 | 20 | 10 | 250 | 8250 |
| B-2 | 13 | 13 | 0.15 | 20 | 20 | 500 | 9200 |
| B-3 | 13 | 13 | 0.25 | 20 | 40 | 1000 | 11900 |
| B-4 | 13 | 13 | 0.65 | 20 | 100 | 2500 | 19200 |
| B-5 | 13 | 13 | 1.25 | 20 | 200 | 5000 | 26500 |

protruding part (Fig. 4). A weight equal to the required tensile force is suspended from the eye of the end piece. Next, the sensing element nut, which was joined to it previously, is tightened up by means of a special spanner or tommy bar until the gap between the nut and the casing is eliminated. After the removal of the weight and the end piece, the protruding part of the sensing element can be cut off.

The natural frequency of the transducers of this series can also be evaluated by the formula given above.

The advantages of transducers of the latter type consist in their ease of assembly and in the possibility of changing their sensitivity by replacing the reluctant body. Moreover the experience of working with transducers of the B series has shown that they possess a smaller tendency to receive transverse oscillations than the transducers of the A series.

The characteristic of the strain-gauge acceleration transducers of the B series is given in Table 2.

The use of wire transducers in the sensitive elements of small dimensions with a curvilinear surface produces many practical difficulties.

For instance it is not always possible to glue the transducers accurately in parallel with the axis of the sensing element. A considerable error is introduced if the base of the strain-gauge transducer approaches in size the length of the sensing element, since in this instance the effective length of the transducer is decreased owing to the effect of the shoulder by means of which the sensing element is fixed to the casing. The use of a wire transducer with a shorter base decreases these defects.

For transducers of the A series with a sensing element 20 mm long it is impossible to use strain gauges with a 10 mm base and for the remaining transducers, gauges with a base of 5 mm.

Transducers of both series can be calibrated in several ways.

For static calibrations a duralumin table (Fig. 5) is screwed on to the protruding threaded part of the sensing element and appropriate weights placed on the table.

Static calibrations of the transducer should be carried out with all the attached equipment including the connecting leads. For dynamic calibrations of the above transducers on normal equipment, no special instruments are required.

When transducers of this type are used for measuring accelerations which do not vary according to the harmonic law, it is necessary to keep in mind that the damping coefficient of the sensing element approaches zero.

# THE STUDY OF A REFERENCE LOADER-SPRING PISTON BAROMETER

K.I. Khansuvarov

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 31-32, July, 1960

A description and brief analysis of a reference loaded-spring piston barometer is given in [1]. Below we describe the results obtained from testing this instrument and determine the range of its application.

Testing this barometer with an error of the order of 0.01 - 0.02 mm Hg represents a complicated problem owing to the continuous variation with time of the measured variable, the atmospheric pressure, according to a complex law. This law is represented by a sum of harmonics with different periods (ranging from several seconds to 24 hours and more) and varying amplitudes. This circumstance makes it very difficult to study high precision barometers. Comparison of instruments which differ in their principle of operation or even in their numerical or design parameters, provides results which depend on the frequency characteristics of the compared barometers and hence differ for different sets of measurements in which the law of pressure variations is different.

The above considerations forced us to divide the study of barometers into three parts. Firstly, two similar models of a given type of instrument were compared. Next the instrument was repeatedly compared with a standard mercury barometer at various atmospheric pressures and different conditions of use. These tests made it possible to find the constant of the instrument.

The evaluation of the errors due to the variations of the atmospheric pressure was made by measuring it with the barometer under test and the Askania Werke Gb5 barometer in parallel.

Results obtained in comparing piston barometers. Barometers 1 and 2 of the latest series produced in the repair and experimental shops of the All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments (VNIIK) were compared to each other. The instruments were placed on the same table and connected to an evacuation system symmetrically through a common vacuum hose, thus ensuring equal residual pressures above the upper ends of the pistons in both instruments; the value of the residual pressure varied between 0.03 and 0.08 mm Hg. The ratio of the areas of the compared barometers was obtained from the ratio of the efforts required for their balancing under the effect of the atmospheric pressure exerted at the time of the measurement; the stability of this relation provides a good idea of the stability of the barometer readings with respect to each other.

The working out of the test results (18 sets of 5 measurements each at 1 min intervals between the readings of each set) provided the following data:

$F_1/F_2 = 1.000003$; $S_1^2 = 51.6 \cdot 10^{-12}$; $S_2^2 = 254 \cdot 10^{-12}$; $\omega^2 = 40.4 \cdot 10^{-12}$; $D(F_1/F_2) = \omega^2 + S_1^2 = 92 \cdot 10^{-12}$ (here $S_1^2$ and $S_2^2$ are respectively dispersions inside a set and between sets of readings; $\omega^2$ is the dispersion which determines the distribution of deviations between the sets).

The dispersion inside the sets $S_1^2$ is due to the errors of the instruments for a given connection of the instruments and a given atmospheric pressure. The proper dispersion between sets $\omega^2$ depends on the errors in determining the "zero", the deviation from the vertical of the instrument axis and other conditions, which makes precise observance in different sets, is impossible.

If we assume that the error of both instruments is the same, the root-mean-square error of each instrument amounts to 0.005 mm Hg.

Direct comparison of the referred areas of the pistons of these two barometers by means of hydrostatic balancing on a liquid press provided the values of $F_1/F_2 = 0.999995$ and 0.999999 with respective dispersions of $25 \cdot 10^{-12}$ and $50 \cdot 10^{-12}$; this data indicates a good agreement of results obtained by either method if the values of the dispersions are taken into account.

Both piston barometers have approximately the same inertia, and hence, the results thus obtained characterise in the main the static errors (reading, solid friction, zero stability, deviation from the vertical of the piston axes, etc.).

Results obtained in comparing the piston barometer with the standard mercury barometer of the All-Union Scientific Research Institute of Metrology (VNIIM). The above data characterise with sufficient completeness the errors and stability of the piston barometer readings. Its basic characteristic, however, which consists in the effective area of the piston, can be best obtained by comparing with a corresponding instrument of a higher order. Therefore we compared in the pressure laboratory of the VNIIM, with the participation of E.F. Dolinskii our barometers under test with the standard mercury barometer of the VNIIM: during the whole of these tests the temperature of the piston barometer varied in the range of 19.15 to 21.05°C and the temperature of the standard barometer in the range of 18.75 to 20.99°C. During one set of readings the temperature of the piston barometer varied by 0.04 to 0.30°C and that of the standard barometer by 0.0 to 0.11°C.

The working out of the test results (15 sets for barometer No. 1 and 17 for No. 2 of 5 readings each at 2-3 min intervals for reading in each set) provided the following data:

Barometer No. 1. $F_1 = 1.000787$; $S_1^2 = 118.4 \cdot 10^{-12}$; $S_2^2 = 672 \cdot 10^{-12}$; $\omega^2 = 111 \cdot 10^{-12}$; $D(F) = \omega^2 + S_1^2 = 229 \cdot 10^{-12}$; Barometer No. 2. $F_2 = 1.000798$; $S_1^2 = 162 \cdot 10^{-12}$; $S_2^2 = 1630 \cdot 10^{-12}$; $\omega^2 = 295 \cdot 10^{-12}$; $D(F) = \omega^2 + S_1^2 = 457 \cdot 10^{-12}$.

The above data provides a ratio of the areas of $F_1/F_2 = 0.999989$. The values of this ratio obtained by direct comparison and the hydrostatic method were respectively 1.000003 and 0.999997. Any of the differences between these three values lies within the boundaries determined by the 99% quartile calculated from the dispersions of the terms in the corresponding difference.

Results of comparing the piston barometer with the Gb5 microbarometer. For the evaluation of the dynamic properties of our barometer its readings were compared with those of microbarometer Gb5 of the Askania Werke Company [2]. Measurements were made in sets of 10-30 measurements each with intervals of 1 min between measurements. In determining the root-mean-square deviations in the readings of the microbarometer Gb5, which is not designed for absolute measurements, a correction equal to the difference between the mean readings of the two instruments in a given set was made. The root-mean-square deviation determined under this condition characterizes sufficiently well the dynamic errors of the piston barometer, which are due to the short-term variations of pressure, since the variations over a period exceeding 10-15 min do not affect to any appreciable extent the value of the dynamic error.

The root-mean-square deviation of the readings of both instruments varied in the different sets of readings between 0.006 and 0.020 mm Hg and amounted to 0.013 mm Hg on the average.

The anlaysis of the measurement results shows that the value of the root-mean-square deviation depends but little on the mean rate of atmospheric pressure variations for the time during which a set of measurements was made, i.e., on the long-term variations of the atmospheric pressure, but in the main is determined by the short-term microfluctuations at the instant of measurement.

Thus in two sets of measurements the mean rate of the atmospheric pressure variations was about the same, but the root-mean-square deviations for one set amounted to 0.02 mm Hg and for the other to 0.007 mm Hg. Measurements of the atmospheric pressure made at 10 sec intervals showed that in the first case short-term microfluctuations were present with relatively large amplitudes. The above data was obtained for a barometer which had springs of a stiffness of 2000 d/cm (the natural frequency was $\alpha_0 = 1.4\ \text{sec}^{-1}$). When springs with a stiffness of 100 d/cm ( $\alpha_0 = 0.3\ \text{sec}^{-1}$) were fixed in the barometer, it became almost insensitive to short microfluctuations of the atmospheric pressure.

Evaluation of the error in measuring atmospheric pressure. The test results provide an evaluation of the error of a piston barometer.

The systematic component of the error consists in the main of the error in determining the referred area of the piston which, as it has been shown before, does not exceed 0.001 %.

The random component of the error is much more difficult to evaluate directly owing to the difference in the frequency characteristics of different barometers.

The Table shows the root-mean-square deviations of the readings, obtained for the comparisons of two VNIIK piston barometers with each other and with the standard mercury VNIIM barometer, and also of the absolute barometer IMA (Japan) with a normal Fuess barometer.

| Compared instruments | Number of measurements | Root-mean-square deviation of readings mm Hg |
|---|---|---|
| Piston barometer No. 1-piston barometer No. 2. . . . . | 90 | 0.007 |
| Standard mercury barometer of the VNIIM- piston barometer No. 1. . . . . | 75 | 0.011 |
| Standard mercury barometer of the VNIIM - piston barometer No. 2 . . . . . | 85 | 0.016 |
| Absolute mercury barometer IMA - normal Fuess barometer [3] . . . . . | 20 | 0.045 [3] |

The results thus obtained show that in comparing the piston barometers with the mercury ones, the deviations in the readings are larger than when the piston barometers are compared with each other. It would appear that this is due to the difference in the inertia of the two types of barometers and the difficulty in comparing a mercury with a piston barometer. On the basis of the data given in the Table and taking into consideration that the root-mean-square deviation of the piston barometer readings and that of the spring microbarometer Gb5 amounted to 0.013 mm Hg, it is possible to assume that the root-mean-square error of the piston barometer is equal to 0.01 mm Hg.

Conclusions. Owing to their high precision and insensitivity to knocks and vibrations during transportation the piston instruments should find wide application for comparing with each other high-precision absolute stationary mercury barometers.

Moreover, these barometers can be used for precision measurements of atmospheric pressure in various metrological and scientific research studies. With very stiff springs these barometers can measure microfluctuations of atmospheric pressure. With low-pressure springs the barometers provide the mean value of the atmospheric pressure.

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# THERMOTECHNICAL MEASUREMENTS

## A NORMAL PLATINUM THERMAL ELECTRODE

B.K. Bragin

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July, 1960

In thermoelectric pyrometry tables of thermal emfs are widely used on the basis of comparing various thermoelectric materials with platinum, which is considered as a so-called normal thermal electrode. From these tables it is possible to determine simply and easily the emf of any pair of thermoelectric materials, thus selecting thermocouples with the required characteristics.

The choice of platinum as a normal thermoelectric material is due to its constant physical properties, chemical inertia, high melting temperature, absence of anisotropy, and because it is relatively easy to purify and machine.

It is known, however, that different consignments of chemically pure platinum, produced in different countries and even inside the same country, can possess different thermoelectric properties. Thus, for instance, the chemically pure platinum produced in the Soviet Union (GOST 8588-57) can have variations in its resistance temperature coefficient $\alpha_{0-100}$ from $3.88 \cdot 10^{-3}$ to $3.925 \cdot 10^{-3}$ and sometimes even larger variations. According to our tests [1] samples of such platinum can develop a thermal emf between them amounting to 100 μv at 1100°C.

Naturally, such a variation in the accepted "zero" makes it impossible to compare the various determinations of thermal emfs obtained in different laboratories. For the same reason it is difficult both to use and classify standard base thermoelectric materials and to fix on a scientific basis tolerances for their thermal emfs.

The standardization of thermoelectric testing can only be achieved if a unified method is introduced based on a single normal platinum thermal electrode for the whole country.

Such a normal platinum thermal electrode called a platinum standard Pt27 only exists in the National Bureau of Standards (USA). According to the published information [2] it consists of platinum wire for which $\alpha_{0-100}$ is equal to $3.922 \cdot 10^{-3}$. In the USA it is customary to express basically any thermal emf with respect to Pt27. Moreover using an auxiliary standard sample made of other materials is not excluded, it is very convenient for determining the thermal emf of electrodes made of the same materials.

The thermometric laboratory of the Sverdlovsk Branch of the All-Union Scientific Research Institute of Metrology (VNIIM), having investigated for several years various thermoelectric materials, has also come to the conclusion about the necessity of using for a normal thermoelectric electrode platinum with a definite characteristic.

For this purpose the Laboratory introduced in 1952 two platinum electrodes with $\alpha_{0-100} = 3.925 \cdot 10^{-3}$, one of which served to check the stability of the thermal emf of the other.

This measure has to a great extent facilitated and speeded up the analysis and comparison of experimental data and helped in the production of better conditioned thermoelectric materials.

In 1958-59 the Sverdlosk Branch of the VNIIM, on instructions of the Committee of Standards, Measures and Measuring Instruments, produced and prepared for general use a group of normal platinum thermoelectrodes (GNPT) intended for obtaining and maintaining unified determination of thermal emfs of different materials referred to a common base. At the same time a draft "Instruction for GNPT" was drawn up in which a brief account was given of the purpose, technical characteristics, standards and rules of application of the GNPT.

The group of normal platinum thermoelectrodes consisted of five samples of standard platinum wire, stabilized by annealing, and made in the Soviet Union, with a purity characterized by the value of $\alpha_{0-100} = 3.927 \cdot 10^{-3}$. The thermoelectrodes of the group have a diameter of 0.6 mm and a length of 1000 mm. In their effective heated part they are protected by tubes of pyrometric porcelain, and in their conducting part by elastic cambric insulation.

The thermal emf of any two thermoelectrodes of a group does not exceed 0.5 μv at a temperature of 1100°C at their working junction. In view of the small value of this paramater various materials can be tested against any of the thermoelectrodes of a GNPT (henceforth we shall denote the thermal emf with respect to a GNPT by $e^t_N$).

The composition of a GNPT is not constant: if one of the elements should be damaged mechanically or its thermal emf should change by ± 3 μv at 1100°C, it should be replaced by a new electrode made of platinum whose $\alpha_{0-100}$ should not be less than $3.927 \cdot 10^{-3}$. For periodic checking of the constancy of the thermoelectric characteristics of a GNPT a completely identical control group of normal platinum thermoelectrodes was made.

The use of a GNPT for direct determination of the thermal emf of various technical materials cannot be considered advisable, since this would lead to their very rapid deterioration. Samples of thermoelectric platinum (OTP) of the 2nd grade are intended for this purpose, and they should be checked against a GNPT by means of samples (OTP) of the 1st grade. All these samples are 1000 mm long, made of platinum 0.5 mm wire with a coefficient $\alpha_{0-100}$ which must not be smaller than $3.920 \cdot 10^{-3}$. In their construction the OTP samples are similar to normal platinum thermoelectrodes.

Under normal operational conditions the heating temperature of the OTP samples must not exceed 1100°C. If it is required to use them at higher temperatures, their calibration within a few microvolts can be obtained by a linear extrapolation of the $e^t_N$ versus temperature curve.

Conclusions. The utilization of the GNPT is an effective and simple method of providing unified thermoelectric testing and will solve several practical problems including:

The comparison and unification of the results of tests carried out at different times and in different places; the statistical working out and analysis of numerous thermal emf evaluations carried out in factory laboratories, which is very important for working out emf tolerances for various thermoelectric materials; a more exact determination of the thermoelectric characteristics of thermoelectrode materials and tables of emfs referred to platinum; working out a more stable technology of production of thermoelectrode materials and methods of checking their quality which would ensure higher quality production;

A simpler checking of the purity of platinum thermoelectrodes and platinorhodium-pantinum thermocouples [1] in industrial and State inspection laboratories for measurement equipment.

With the GNPT now made generally available, it is advisable to add to the existing methods of evaluating the quality of thermoelectric materials the following instructions:

To determine the value of $e^t_N$ at least at one temperature (for instance, 1100°C) for the produced thermoelectric platinum and note it in the production certificate of the wire; to use for determining the thermal emf and classifying standardized base metal thermoelectrode materials, only platinum which has a determined thermal emf with respect to a GNPT, and to note the values thus obtained on the production certificate of the classified material.

In future it will be necessary to establish binding standards for the thermal emf of the produced thermoelectrode materials, taken with respect to a single normal platinum thermal electrode.

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# DIFFERENCES IN THE RELATION BETWEEN RESISTANCE AND TEMPERATURE OF SEVERAL GRADES OF PLATINUM IN THE RANGE OF 10.8 to 273.16°K

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The advantages of referring the readings of platinum thermometers to a standard table by means of Matthiessen's rule as compared with determining the temperature according to the International Temperature Scale (ITS) specification have been discussed in detail in [1, 2].

The advantages consist in the fact that with almost no loss in the reproducibility of the scale a gain is made in the simplicity of calibration (reference points of melting ice and boiling oxygen only), in the simple transition from resistance to temperature and in the possibility of extending the limits set by the ITS without changing the technique or losing accuracy.

The latter is especially important since the extension of the ITS to 20°K is a question of the near future. On the basis of what is known about the temperature characteristic of platinum below 90°K, it is possible to assume that down to 50-40°K it is advisable to use for the conversion of resistance to temperature the standard table and Matthiessen's rule. But for lower values, especially between 20 and 10°K where the practical limit of measurements by means of a platinum thermometer lies, the method of converting resistance values of any thermometer to the corresponding values on the standard scale is not yet clear.

In papers [3-8] methods of referring the scale of any given platinum thermometer to a standard scale are suggested and described. However they are based on insufficient experimental data and only deal with referring scales of one particular grade of platinum in the range of 20-90°K.

We consider that only an experimental investigation of the temperature resistance characteristic of many grades of platinum over a wide rage of temperatures can provide sufficient data for the choice of a method of referring the readings of platinum thermometers to the standard table. With this object in view we undertook the present work.

Thermometers. For investigating the relation of the resistance of platinum to temperature, 10 thermometers of the P.G. Strelkov design [9] were made. Moreover we were able to include a British thermometer given to us by S.P. Barber (National Physical Laboratory, Britain). We investigated 11 types of platinum thermometers whose coefficients $W_{100°C}$ lie in the range of 1.3918-1.3925, so that all the thermometers satisfied the 1948 ITS requirements with respect to the purity of the platinum. The grades under test were refined in different ways and divided for this purpose into three groups.

The characteristics of the different grades of platinum are shown in Table 1.

For the determination of $W_{100°C}$ all the thermometers were calibrated at the melting ice and boiling oxygen points.

Measuring equipment. Measurements between 10.8 and 273.16°K were made in an adiabatic cryostat [11], but the unit of the gas thermometer was changed for a copper comparison unit with 16 holes into which the group standard and tested thermometers were inserted in a thin layer of a vacuum paste. The unit was wound with a constantan wire heater; the leading-in wires were glued to the unit by the BF-2 glue in order to avoid heat conduction along them and then connected to a plexiglas ring with contact pins which were mounted on the unit. The temperature drift of the unit amounted during measurements to $1 \cdot 10^{-4}$ degrees/min. The cycle of measurements at each temperature point lasted about 30 min.

TABLE 1

| Thermometer | Value of $W_{100}$°C | Type description |
|---|---|---|
| IKh-6 | 1.39251 | Soviet made and refined by the Institute of General and Inorganic Chemistry of the Acad. Sci USSR [10] |
| IKh-5 | 1.39217 | |
| IKh-4 | 1.39242 | |
| IKh-3 | 1.39178 | |
| Pt-50 | 1.39205 | Soviet made and commercially refined |
| Pt-51 | 1.39215 | |
| P-12 | 1.39247 | |
| AM-I | 1.39228 | Foreign made |
| AM-II | 1.39206 | |
| AM-III | 1.39209 | |
| B | 1.39250 | |

Note. The designation AM refers to platinum samples used for thermometric purposes by the NBS (USA). The NBS presented these samples to one of the authors of this article in 1945 for him to acquaint himself with the thermoelectric properties of the samples. Thermometer B was sent by the NPL (Britain).

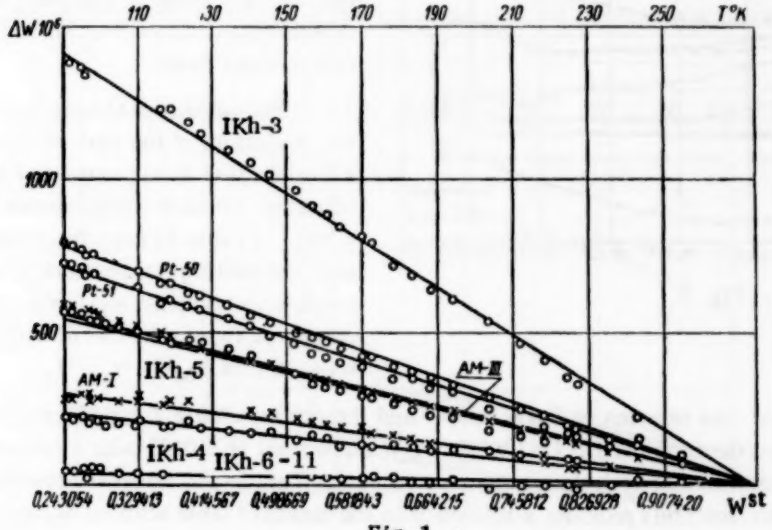


Fig. 1

The resistance was measured on a low-resistance Diesselhorst potentiometer, with standard resistance coils. The measuring current through the thermometer was maintained at 1 ma for temperatures about 20°K and at 1.5 ma for temperatures between 10 and 20°K. The sensitivity of the measuring circuit provided an accuracy down to $1 \cdot 10^{-4}$% above the boiling point of hydrogen, and down to $1 \cdot 10^{-3}$% below this boiling point.

The refrigerants consisted of liquid and solid (under rarefaction) hydrogen (10.8-55°K), and liquid and solid (under rarefaction) nitrogen (51-200°K) and a mixture of solid carbon dioxide with ethyl alcohol (above 200°K).

Measurements in the range of negative temperatures of the ITS (90.19-273.16°K). The resistances were compared at 30 temperature points with intervals of 6° for the majority of the thermometers. Eight of the thermometers under test (the P-12, Am-P and B thermometers were not tested in this range) were compared with thermometer IKh-6-6 (of the group standard). The temperature T at which the comparisons were made, was determined from the measured value of $W_T^{IKh-6-6}$ by means of the Callendar-Van Dusen equation. The $\alpha$ and $\beta$ constants of the IKh 6-6 thermometer were determined in the normal manner before the thermometer was mounted in the cryostat. It was not advisable to determine constant $\delta$ directly, so as not to heat up the thermometer to the boiling point of sulfur. This thermometer was given the value of $\delta$ obtained for another thermometer made of the same grade of platinum, and it was considered that the value of the error thus committed amounted to $\delta = 3.7 \cdot 10^{-3}$ (this was the dispersion of $\delta$ values of a group of 15 thermometers of the same grade tested previously [12]).

TABLE 2

| thermometer | β | δ | M.10$^{-6}$ | thermometer | β | δ | M.10$^{-6}$ |
|---|---|---|---|---|---|---|---|
| IKh-6–11 | 0.1121 | 1.4899 | 58 | Pt-50 | 0.1165 | 1.4820 | 1046 |
| IKh-5 | 0.1133 | 1.4922 | 754 | Pt-51 | 0.1133 | 1.4861 | 963 |
| IKh-4 | 0.1121 | 1.4896 | 293 | AM-I | 0.1147 | 1.4911 | 375 |
| IKh-3 | 0.1109 | 1.4963 | 1852 | AM-III | 0.1174 | 1.4856 | 762 |

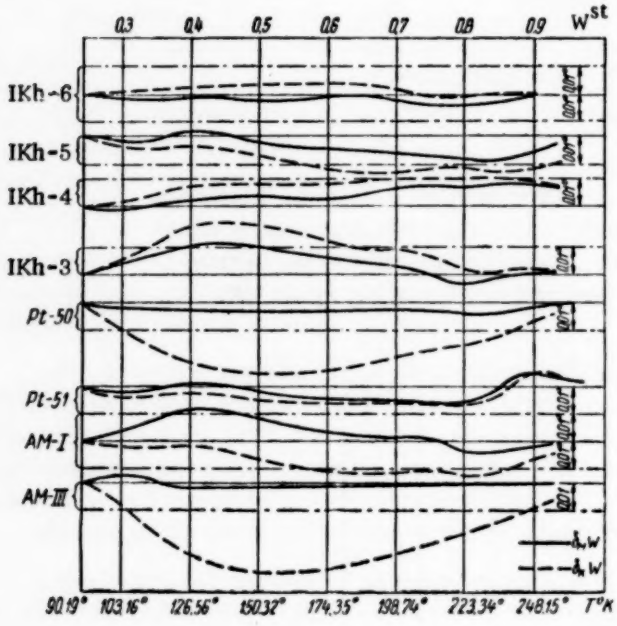


Fig. 2

At the same time as the $W_T^{IKh-6-6}$ of the standard thermometer was measured, the $W_T$ of the thermometers under test were also measured and for each of them the value $\Delta W_T = W_T - W_T^{IKh-6-6}$ was calculated, which characterized the deviation of the particular grade of platinum from the standard. The relation of $W_T$ to T in the range of 90-273.16°K and the corresponding values of $W_T^{IKh-6-6} = W_T^{st}$ for all the thermometers is shown in Fig. 1, from which it will be seen that, for all grades of platinum under test over the whole range of negative temperatures of the ITS the relation between the $W_T$ of any grade and the $W_T^{st}$ of the standard grade is linear: $\Delta W_T (W_T^{st})$ are straight lines. In other words, in this temperature range it is possible to refer the individual thermometer scale to the standard ones according to Matthiessen-Nernst by using the approximate relation:

$$W_T = W_T^{st} + M(1 - W_T^{st}),$$

where $W_T$ and $W_T^{st}$ are the resistivities of the given and the standard grade of platinum and M is a constant determined from calibrating the thermometer at one temperature point.

The validity of Matthiessen's rule is shown by the deviations of the path of experimental points from a straight line as indicated in Fig. 1. In fact if we calculate for each thermometer $M = W_{O_2} - W_{O_2}^{st} / 1 - W_O^{st}$ (Table 2) from the values of the resistances near the boiling temperature of oxygen, it becomes possible to compute $W_M = W_T^{st} + M(1 - W_T^{st})$ and having compared them with the directly measured values $W_{ex}$, to find $\delta_M W = W_M - W_{ex}$.

Fig. 2. represents the relation of $\delta_M W$ to $W_T^{st}$ and the corresponding T (full lines) for all the thermometers. Only in the case of two thermometers is (~140°K) $\delta_M W$ equivalent to 0.011° over a narrow temperature range; for all the remaining thermometers it does not exceed 0.010°. Thus in the interval between 0°C and the boiling point of oxygen Matthiessen's rule provides a reference to the standard table with an accuracy of 0.01°.

By using the same experimental material we can compare the identity of scales calculated by means of the ITS instructions for all the thermometers under consideration. The thermometer constants are given in Table 2, where the values of δ do not refer to the thermometers under consideration, but to other thermometers made of the same grade of platinum. This substitution, as it was pointed out before, produces an error of $\delta \simeq \simeq 3.7 \cdot 10^{-3}$ which corresponds to an uncertainty in determining the temperature of ~0.005°.

By calculating the value of $W_k$ by means of the Callendar-Van Dusen formula for each thermometer and comparing the value thus obtained with the directly measured value of $W_{ex}$, we found $\delta_k W = W_k - W_{ex}$. Fig. 2 shows the relation of $\delta_k W$ to $W_T$ and the corresponding values of T (dotted lines) for all the thermometers. In three out of eight thermometers the error in referring, according to the ITS formula, exceeds 0.015°, which is the uncertainty in determining the temperature, and consists of the error in calibrating and the error due to the substitution of δ. Thus the identity of scales of the thermometers under consideration as determined by the ITS method is not better than the one obtained by referring them to the standard scale by Nernst's method. This conclusion, arrived on the basis of experimental investigation of modern highly pure grades of platinum, provides the possibility of calculating the temperature by the resistance of platinum by means of the standard table according to Nernst which, as it was already pointed out, presents considerable advantages [1, 2].

Measurements in the temperature range of 10.8-90.19°K. Measurements of the thermometer resistance were made in this range similar to the 90.19-273.16°K range. Comparisons were made for the majority of thermometers at 44 temperature points in intervals of 2° (for 4 thermometers no measurements were made in the 40-50°K range owing to defects in the measuring circuit).

The thermometers under test were compared with those of the reference group IKh-6-6 and IKh-6-5. From the individual measurements of $W_T^{IKh-6-6}$ and $W_T^{IKh-6-5}$ and individual corrections to the reference thermometers the mean values of $W_m^{IKh-6}$ were found, which made it possible to calculate by means of standard tables [13] the temperature T at which the measurements were made. The difference between the corrected values of two reference thermometers did not exceed at any point a value equivalent to 0.0005°.

At the same time the values of $W_T$ of all the thermometers under test were measured and the value of $W_T = W_T - W_m^{IKh-6}$ found, thus obtaining the deviation of the resistivity of any given grade of platinum from the standard grade. The relation of $\Delta W_T$ to T and the corresponding values of $W_m^{IKh-6} = W_T^{st}$ in the temperature interval of 11-90°K for all the thermometers is shown in Fig. 3, from which it will be seen that both the value of $\Delta W$ and the shape of the curves $\Delta W(T)$ are different for different grades of platinum.* The values of $\Delta W$ for Soviet Laboratory refined-and American-platinum characterize the purity of the platinum, as it was reverled by the data obtained from the semiquantitative analysis carried out at the optical laboratory of the D.I. Mendeleev All-Union Scientific Research Institute of Metrology. But the shape of the curves $\Delta W(T)$, it would appear, are determined not only by the purity of the platinum but also by the composition of the impurities. In fact the shape of curves $\Delta W(T)$ for the platinum of the first group is approximately the same, despite the considerable difference in the purity of individual samples (IKh-3 and IKh-6). The two platinum samples of the second group have very similar $\Delta W(T)$ curves. The curves of the American platinum differ considerably in their shape from the others. But the shape of the British platinum curve is close to that of the standard platinum IKh-6 curve.

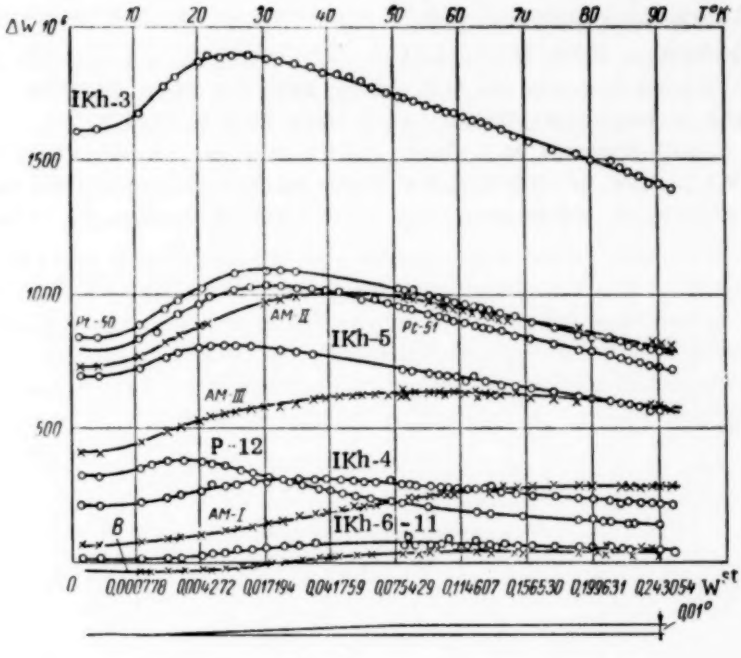


Fig. 3.

The characteristic feature of all the $\Delta W(T)$ curves consists in their being straight only in the range of the nitrogen temperature and deviating from a straight line at lower temperatures; the temperature at which deviation begins, and the value of the deviation differ for various brands of platinum.

*The measurements of $W_T$ of all the thermometers tested in the range of liquid helium temperatures are also given here.

A careful study of the results shows that especially large deviations from linearity between the W of a given brand and the W of the standard brand in the range of 30-10°K amounts to 2° at the end of this range.

Thus below 50°K Matthiessen's rule no longer holds, and it is no longer possible to use Nernst's method for referring scales of individual thermometers made of different brands of platinum to the standard scale. Even the referring of the scales of thermometers made of the same brand of platinum to the scale of that brand by means of calibrations at two points (the boiling of $H_2$ and $O_2$), cannot ensure accuracy better than 0.01 - 0.02° in the range of 90-20°K and an accuracy of 0.05-0.08° in the range of 20-12°K.

Conclusions. The resistivity characteristic of platinum thermometers of different origins ($1.39178 \leq W_{100°C} \leq 1.39251$) was studied in the range of 10.8-273.16°K and it was established that Nernst's reduction formula holds in the range of 273-50°K with an error of 0.01° and does not hold at temperatures lower than 50°.

The applicability of Matthiessen's rule made it possible to suggest a simple method for calibrating and computing temperature, which extends the range of platinum thermometers [1, 2] down to the nitrogen boiling point with an error not larger than the one guaranteed by the ITS calibration method.

The inapplicability of Matthiessen's rule at temperatures below 50°K makes it necessary to adopt a critical approach to various reduction methods [3-8].

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*See English translation.

# CHECKING THE SENSITIVITY OF DIFFERENTIAL RESISTANCE THERMOMETERS IN UNBALANCED BRIDGE CIRCUITS

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July, 1960

In unbalanced bridge circuits used with differential thermometers either two adjacent or all the four arms of the bridge are made variable. In the latter case the sensitivity and accuracy of the differential thermometers is increased, especially when small temperature differences are measured.

Below we analyze a circuit with four variable arms. The proposed method of controlling the sensitivity by means of regulating resistors made of the same material as the transducers is also applicable, however, to bridge circuits with two variable arms.

In a bridge with four variable arms, two identical metal resistors R are wound on a common former and serve as one of the transducers of the instrument (see figure). Two identical resistors R' comprise the second transducer. It is easy to prove by means of Kirchhoff's laws that the current in the galvanometer connected in the zero diagonal of the bridge will be determined by the expression:

$$I=\frac{V(R-R')}{R_G(R+R')+2RR'}, \tag{1}$$

where V is the voltage fed to the bridge diagonal; $R_G$ is the galvanometer resistance.

If the current is read on the galvanometer scale in graduations (N) and each graduation is equal in amperes to $C_a$ we have:

$$N=\frac{V}{C_a}\cdot\frac{R-R'}{R_G(R+R')+2RR'}. \tag{2}$$

Let us take $dN/d(\Delta t)$ as the sensitivity of a differential thermometer which indicates how many divisions the galvanometer pointer will be deflected when measuring a transducer temperature difference $\Delta t$ of 1°. In order to simplify further calculations, let us simplify expression (2) by taking advantage of the fact that the temperature differences measured by means of differential thermometers are usually relatively small, and therefore the differences in resistances R and R' are considerably smaller than the resistances proper. Assuming that in the numerator of (2) $R-R' = R\alpha\Delta t$ ($\alpha$ is the temperature coefficient resistance of the transducer) and in the denominator $R=R'$ we obtain:

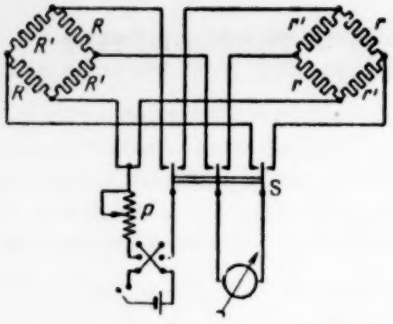
$$N=\frac{V}{C_a}\cdot\frac{\alpha\Delta t}{2(R_G+R)}. \tag{3}$$

Whence

$$\frac{dN}{d(\Delta t)}=\frac{V}{C_a}\cdot\frac{\alpha}{2(R_G+R)}. \tag{4}$$

Let us include in the circuit for reference purposes a square former common to four resistors r, r, r' and r' in which r differs slightly from r'. Then similarly to (2) the position of the galvanometer pointer, when the thermometer sensitivity is checked (the right-hand side position of switch S), will be determined by the expression.

$$N_\kappa=\frac{V}{C_a}\cdot\frac{r-r'}{R_G(r+r')+2rr'} \tag{5}$$




and if we assume that in the denominator r = r' we have:

$$N_\kappa = \frac{V}{C_a} \cdot \frac{r - r'}{2r(R_G + r)}. \tag{6}$$

If the reference resistors r and r' are made, as usual, from metals with a negligible temperature coefficient (stable reference resistors), the values in (6), which will change between measurements, will consist of V, $C_a$ and $R_G$

If r and r' are made from the same material as the transducer (variable control resistors) and their relation to temperature is represented by

$$r = r_0 e^{\alpha t}; \quad r' = r_0' e^{\alpha t}, \tag{7}$$

where t is the temperature of the reference resistors, the expression for $N_k$ with (7) included in it will assume the following form after transformations

$$N_\kappa = \frac{V}{C_a} \cdot \frac{r_0 - r_0'}{2r_0(R_G + r)}, \tag{8}$$

from which it will be seen that in this case the variation of the reference position of the galvanometer pointer between measurements will be determined by the variations of the values of V, $C_a$, $R_G$ and r.

The relative variation of the sensitivity of a differential thermometer due to the variations of the circuit parameters (V, $C_a$, $\alpha$, R, and $R_G$) can be calculated from (4)

$$\Delta \ln \frac{dN}{d(\Delta t)} = \Delta \ln \frac{V}{C_a} + \Delta \ln \alpha - \frac{\Delta R_r + \Delta R}{R_G + R}. \tag{9}$$

At the same time, the relative variation of the reference position of the galvanometer pointer, due to the variations of the circuit parameters, is equal in the case of constant reference resistor to:

$$\Delta \ln N_\kappa = \Delta \ln \frac{V}{C_a} - \frac{\Delta R_G}{R_G + r}, \tag{10}$$

and in the case of variable resistors to:

$$\Delta \ln N_\kappa = \Delta \ln \frac{V}{C_a} - \frac{\Delta R_r + \Delta r}{R_G + r}. \tag{11}$$

Before the measurements are started, the reference resistors are switched in (the right-hand side position of switch S) and the galvanometer pointer is set by means of potentiometer P to its reference position $N_k$ which corresponds to $\Delta \ln N_k = 0$. Hence taking into consideration (10) and (11), equation (9) can be rewritten for condition $\Delta N_k = 0$ and $r \approx R$ as follows:

For the case of constant reference resistors:

$$\Delta \ln \frac{dN}{d(\Delta t)} = \Delta \ln \alpha - \frac{\Delta R}{R_G + R}, \tag{12}$$

and for the case of variable reference resistors

$$\Delta \ln \frac{dN}{d(\Delta t)} = \Delta \ln \alpha - \frac{\Delta(R - r)}{R_G + R}. \tag{13}$$

In the right-hand side of (12) the second term is usually the larger which determines the considerable and directly uncontrollable variation in the sensitivity of the thermometer if the reference resistors are constant.

The following conclusions can also be made from (12) and (13); if the temperature $t_2$ at which $\Delta t$ is measured is considerably different from temperature $t_1$, at which the differential thermometer is calibrated in the case of constant reference resistors, a systematic error can be committed which will increase with a rising difference $t_2 - t_1$; if however reference resistors are made of the same material as the transducers, then by choosing $R_0 = r_0$ and by placing the reference resistors near the transducers so as to make the temperature of the reference resistors follow that of the transducers, it becomes possible to ensure a correct and exact control of the differential thermometer sensitivity both for $t_2 = t_1$ and for a $t_2$ differing considerably from $t_1$.

Conclusions. The proposed method of controlling the sensitivity of differential resistance thermometers is especially effective when not only the temperature differences, but also the temperatures themselves, vary greatly. However in the case of temperatures which vary but a little the use of the reference resistors made of the same material as the transducers is advisable owing to their smaller cost and better possibilities of eliminating parasitic thermal emfs in the circuit.

# ELECTRICAL MEASUREMENTS

## A NEW UNIVERSAL DC POTENTIOMETER UPL-60

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The low-and high-resistance potentiometers now being produceddo not meet, with respect to their accuracy, all the requirements for testing modern high-grade instruments, and in principle do not differ from the potentiometers whose circuits have been developed many years ago, when digital display instruments of grades 0.1 and 0.05 were not being manufactured.

Assuming that increasing the number of potentiometer types is economically unsound, we consider that it is advisable to replace the various laboratory-type dc potentiometers now being manufactured by a single universal potentiometer.

Below we describe a new universal dc potentiometer UPL-60 developed by the L'vov "Teplokontrol'" plant for direct accurate measurements of emfs and voltages by means of the compensation method, and for use as a source of a standard voltage.

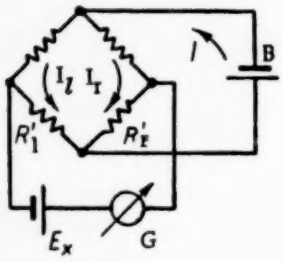


Fig. 1

Potentiometer UPL-60, based on potentiometer KL-48 now being produced by the plant, is designed as a bridge circuit (Fig. 1). One of the diagonals contains the source of the operating current B and the other diagonal has the galvanometer G and the object of measurement with the unknown emf $\epsilon_x$ connected across it.

At the instant of compensation when the current through the galvanometer is equal to zero, the following equality holds:

$$e_x = I_l R_{1l} - I_r R_{1r} =$$
$$= (I_l + I_r)\left(\frac{I_l}{I_l + I_r} R_{1l} - \frac{I_r}{I_l + I_r} R_{1r}\right) = IR,$$

where $I_l$ and $I_r$ are the currents in the left-and right-hand sides of the potentiometer branches; $R_{1l}$ and $R_{1r}$ are the compensating resistors of the left-and right-hand sides of the potentiometer branches. I is the operating current of the potentiometer; R is the compensating resistance read off the potentiometer.

The schematic of the potentiometer is shown in Fig. 2.

The double decades II-II', III-III' and IV-IV' are made in such a manner that the sum of their resistances in the circuit of the basic and complementary decade is always constant. The resistance of each coil, decades I, II, III and IV, is given in Fig. 2 and the variation in the resistance of decades V and VI when the wipers are displaced to the adjacent contact amounts to 0.0011 ohm.

All the decades except I and II are supplied with contacts "-1" which can be used for a simplified checking of the potentiometer.

The operating current is fed to the wipers of decade II (point aa) and then divides along two branches: the "left" one containing decades I, III and V and the "right" one containing decades IV and VI. The resistance of the left branch is set at 495 ohms by means of building-out resistors and that of the right branch at 4950 ohms, thus making the current $I_l$ ten times larger than $I_r$.

The object of measurement is connected to the "2 v", "0.1 - 0.01 v", or "1 v" and "-" terminals. Terminal "-" is a common one. When connection is made to the 2 v terminal the measuring limit of the potentiometer amounts to 2.511110 v and the operating current is 10 ma. When connection is made to the 0.1 v terminal and the plug connector P is in position 2 (n = 0.1), the measuring limit is 0.11111 v and the operating current

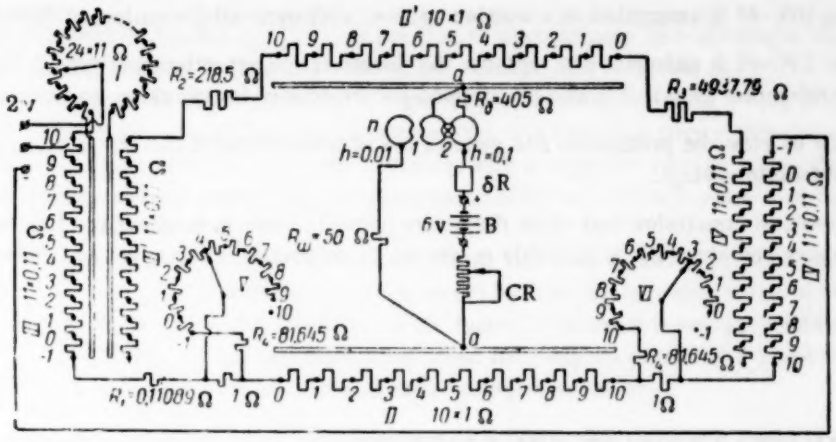


Fig. 2. I)First single decade(×n); II) second basic decade (× 0.1n); II') second complementary decade; III) third basic decade (× 0.01n); III') third complementary decade; IV) fourth basic decade (× 0.001n); IV') fourth complementary decade; V) fifth single decade (× 0.0001n); VI) sixth single decade (× 0.00001n); SR - setting resistance, CR-control resistance.

remains at 10 ma. When the plug is placed in position 1 (n= 0.01),the measuring limit becomes 0.0111110 v and the operating current becomes 1 ma. Thus the UPL-60 potentiometer has three measuring limits.

It will be seen from the above that the basic peculiarity of the UPL-60 potentiometer is its use in a high-resistance connection with a low-resistance potentiometer circuit, thus decreasing the effects of contact emfs and thermal emfs which arise from the displacement of wipers. When wipers of the II, III, IV, V or VI decades are displaced these emfs do not affect the operation of the circuit. The parasitic emfs which arise when the wipers of decade I are displaced do not affect the operation of the circuit either, since firstly they are superimposed on a voltage exceeding 0.1 v and secondly from the instant I is used,to the final balancing of the bridge,sufficient time elapses for the emfs which arise during the displacement of the wipers to have almost completely disappeared.

Another advantage of the UPL-60 potentiometer, when used in the high-resistance connection, consists in the resistance of the galvanometer circuit,changing when balanced by means of decade I,from 14 to 130 ohms only as compared with variations from 0 to 5000 and even to 10,000 ohms common for normal potentiometers. This circumstance makes it possible to use less sensitive galvanometers and facilitates its use in the unbalanced condition. When measuring in the limits of 0.111110 and 0.0111110 v when decade I is not in use, the resistance of the potentiometer in the galvanometer circuit remains constant at 14 ohms.

The disadvantage of the UPL-60 potentiometer consists in its relatively large operating current of 10 ma as compared with 0.1 ma in normal potentiometers. It should be, however, noted that this defect is not important at the present time since by using as the source of current dry batteries of the "Deviz" type, whose capacity amounts to 500 ampere-hours, it is possible to obtain sufficiently stable supplies lasting several years with a continuous use of the potentiometer.

The basic error of potentiometer UPL-60 does not exceed

$$\Delta = \pm (1.5 \cdot 10^{-4} V + 2m \cdot 10^{-6} V_t) b,$$

where V is the potentiometer reading, v; $V_t$ is the top measuring limit, v; m is the number of decadeswhose reading is not equal to zero.

The variation in the reading of the potentiometer with ambient temperature changes of ± 1°C does not exceed $2 \cdot 10^{-5} V_t$ in the temperature range of + 15 to + 25°C.

The resistance of the potentiometer in the operating current circuit amounts to 550 ohms, the voltage drop across the setting resistance in the operating current circuit is equal to 1.0191 v.

Potentiometer UPL-60 is assembled in a wooden cabinet with over-all dimensions of 220×340×555 mm.

Potentiometer UPL-60 is universal and replaces the double range potentiometer type R-330, the six-decade high-resistance potentiometer type R-375 and the stepped-potentiometer for checking wattmeters.

From this point of view the production and general use of potentiometer UPL-60 is most expedient since it will provide considerable savings.

It should be noted in conclusion that since the above potentiometer is, in effect, the first one of a universal type both in our country and abroad, it is desirable to discuss its properties, advantages and defects.

# INDUCTIVE COMPENSATION OF THE ERROR DUE TO THE SHAPE OF THE CURVE IN SIMPLE RECTIFYING VOLTMETER CIRCUITS

K.B. Karandeev and I.A. Zkhariya

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The effect produced by inductance in the measuring circuit of a rectifying instrument is opposite to the effect produced by the self-capacitance of a rectifier; this phenomenon was used for compensating the frequency error of rectifying instruments [1, 2, 3]. The inductive compensation can be obtained from the inductance of a moving coil instrument, which is a characteristic feature of the majority of rectifying instruments. This inductance is particularly large in recording instruments. In certain cases it is advisable to connect an additional coil in series with the moving coil of the instrument [4].

The error produced by the distortion of the current or voltage wave shape is at present reduced by choosing a root-mean-square operating portion of the voltampere characteristic of the rectifier, or more often by means of the so-called parametric compensation. In the first instance a reduction of the error due to the nonsinusoidal wave shape is accompanied by a rise in the frequency error and also of the temperature error. In the second case [3, 5] highly loaded rectifiers are used; a decreased error due to the wave shape is attained by the introduction of capacitances which alter the rectification condition in such a manner that the error due to the nonsinusoidal shape of the wave is reduced in a certain range of wave shape and frequency variations of the measured object. This compensation can be called a capacitative correction.

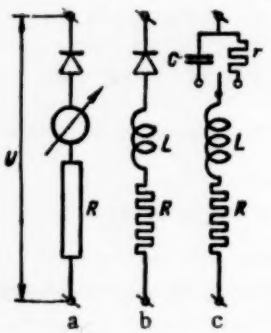

Fig. 1

To date no attention was paid to the possibility of inductive compensation. The object of the present work consists in finding the nature of the inductive effect on the error due to the nonsinusoidal wave shape of the measured voltage.

1. A rectifying voltmeter with a simple half-wave rectifying circuit (Fig. 1a) is fed with a variable frequency voltage of a waveform shown in Fig. 2. For $\alpha = 1$ this voltage is rectangular; for $\alpha \to 0$ it becomes peaked. Such a waveform of the measured voltage is the result of a simplified representation of a family of curves described by an elliptical function [6]. In order to analyze the errors due to the effect of the waveform it is possible to use another family of curves, but the above waveform is widely used for this purpose. [7, 8].

In the case of a heavily loaded recifier it is possible to approximate its voltampere charactristic and the relation of its self-capacitance to the applied voltage by a broken line as shown in Fig. 3. The piecewise linear approximation makes it possible to substitute for a rectifier a circuit containing a switch (Fig. 1c): for a positive voltage across the rectifier the measuring circuit includes the rectifier resistance r; the switching occurs at the instant the sign of the voltage changes across the rectifier; with a negative voltage across the rectifier its resistance is equal to infinity and the measuring circuit contains only the self-capacitance of the rectifier.

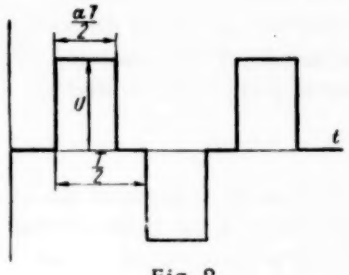

Fig. 2

We can determine the dc component of the current in the measuring circuit according to (9) by finding the mean value of the voltage across the rectifier. If the latter is known it is not difficult to determine the error of the instrument when the frequency (period T ) and the shape (coefficient $\alpha$) of the measured voltage are varied.

The sequence in determining the mean value of the voltage across the rectifier is best analyzed on an example of an aperiodic measuring circuit which does not contain inductance. Fig. 4 shows voltage curves across the rectifier in separate intervals of the measured voltage period; by the side of the intervals are shown the equivalent measuring circuits which correspond to recifier circuit shown in Fig. 1b . Taking into consideration the initial conditions of each interval it is not difficult to determine the voltage across the rectifier:

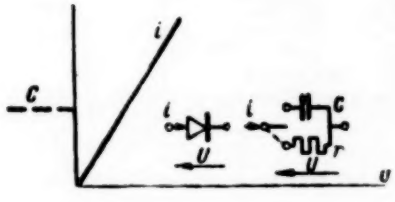

Fig. 3

$$
\begin{aligned}
u_1 &= U\left(1-e^{-\frac{t}{\tau}}\right);\quad \tau=RC;\\
u_2 &= U_0 e^{-\frac{t}{\tau}};\\
u_3 &= U_0' - (U+U_0')\left(1-e^{-\frac{t}{\tau}}\right);\\
u_4 &= -U\frac{r}{R+r}.
\end{aligned}
\qquad (1)
$$

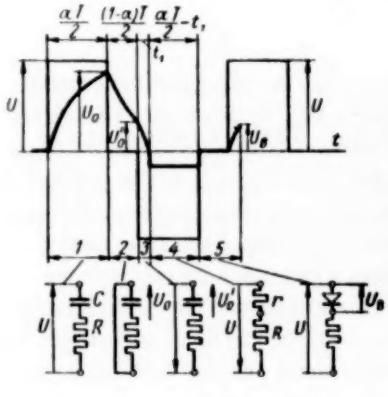

Fig. 4

For the above expressions the time is calculated from the beginning of each interval; the equations include the values which determine the initial conditions: for instance, in the second interval the applied voltage is equal to zero, however capacitance C discharges voltage $U_0$ into the measuring circuit, i.e., it discharges the voltage to which it had time to be charged during the first interval of time. Hence for determining $U_0$ the following equation holds:

$$U_0=(u_1)_{t=\frac{\alpha T}{2}}.$$

Thus, in order to determine all the values characterizing the initial conditions of the processes in the measuring circuit, we should obtain equations whose solution provides the required values of $U_0$, $U_0'$ and $t_1$:

$$U_0=(U_1)_{t=\frac{\alpha T}{2}};\quad U_0'=(u_2)_{t=\frac{1-\alpha}{2}T};\quad (u_3)_{t=t_1}=0. \qquad (2)$$

It will be seen from Fig. 4 that switching-in the rectifier circuit occurs at the end of the third and fourth intervals. In order to determine the mean value of the voltage across the rectifier, it is necessary to find the integrals of expressions (1) in the limits indicated in Fig. 4 and add them algebraically. By adopting abridged notations:

$$\frac{2\tau}{T}=2\tau f=x;\quad \frac{r}{R+r}=k,$$

we obtain:

$$U_c=U\frac{1-k}{2}\{\alpha-x\ln[1+e^{-\frac{1}{x}}(e^{\frac{\alpha}{x}}-1)]\}. \tag{3}$$

The measuring circuit remains aperiodic even with a small inductance. The critical condition is the limiting aperiodic condition which determines the character of the processes in the first interval of the period shown in Fig. 4. It is known [10] that in the aperiodic condition the impedance function of the measuring circuit has two real poles, one common real pole in the critical condition and two complex poles in the oscillatory condition.

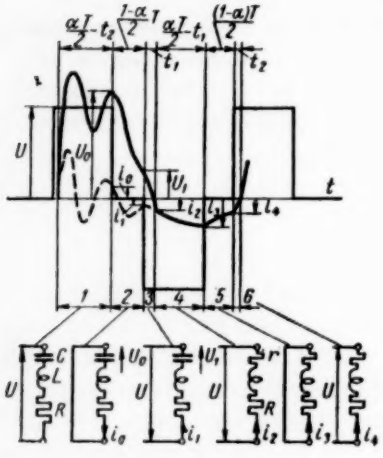

Fig. 5.

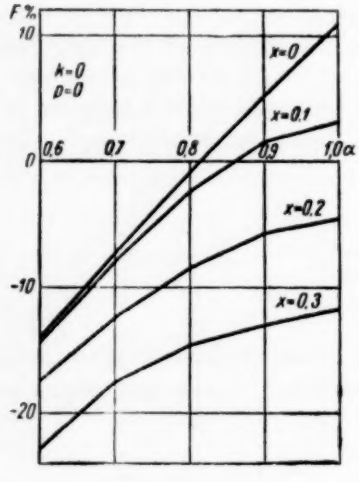


Fig. 6.

These expressions determine the relations between elements of the measuring circuit for various conditions of operation. It can be shown that the condition of the circuit shown in Fig. 1b is characterized by the value p:

$$p=\frac{L}{CR^2}. \tag{4}$$

For a critical condition p= 0.25, for an aperiodic one p < 0.25 and for an oscillating condition p > 0.25.

Inductance in the measuring circuit hinders considerably the determination of the mean voltage across the rectifier, since the initial conditions in this instance are determined not only by the initial voltage across the capacitance, but also by the initial current through the inductance.

The diagram of the voltage across the rectifier and the current through the measuring circuit is shown in Fig. 5; this figure also shows the equivalent circuit for each time interval of one period in the measuring circuit. Similarly to the case shown in Fig. 4, it is also possible in this instance to derive differential equations by assuming that the beginning of each interval of time is the beginning of the time count. The solution of these equations provides expressions for the separate sections of the voltage curve across the rectifier and the current curve in the measuring circuit. The initial conditions in these expressions are determined by the initial values of the current and the voltage, equal to their final values in the preceeding sections. On this basis nine equations can be derived (including two transcendental ones) for determining $U_0$, $i_0$, $u_1$, $i_1$, $i_2$, $i_3$, $i_4$, $t_1$ and $t_2$. The system of these equations can be solved by the method of consecutive approximations assuming that at the beginning $t_2 \simeq 0$. The value of $t_2$ obtained at the end of the calculation can be substituted for a second time and thus a second approximation obtained; however, calculations show that in practice one approximation is sufficient. The second approximation is sufficient for determining $t_1$.

The sequence of determining the mean value of the voltage across the rectifier for the critical and oscillating conditions remains the same as the one described above. In this instance, however, we do not show all the corresponding calculations and expressions owing to their length. In a general form the mean voltage across the rectifier can be represented by the following expression:

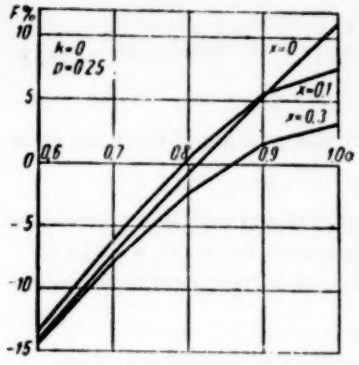


Fig. 7.

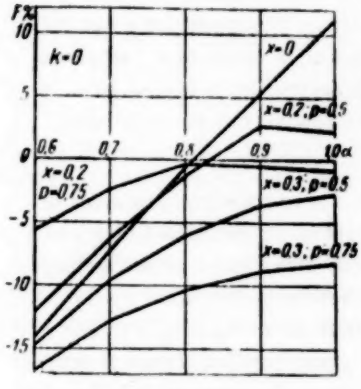


Fig. 8.

$$U_c = Uf(a, x, p).$$

2. The error in measuring a nonsinusoidal voltage of a given frequency is determined by the difference of the mean values of current in the indicator when a nonsinusoidal voltage is measured and when the circuit is calibrated at a sinusoidal low-frequency voltage; the effective values of the voltage in either case should be the same.

The form factor of the family of curves in Fig. 2 is

$$k_f = \frac{U_{ff}}{U_c} = \frac{1}{\sqrt{a}}. \qquad (6)$$

Since the instrument is calibrated by a voltage with $k_f = 1.11$, the form factor for a voltage as shown in the curves in Fig. 2 is $\alpha = \alpha_c = 0.812$.

The errors in measuring the sinusoidal voltage are represented by the following equation:

$$F = \frac{I_m - I_{mc}}{I_{mc}} = \frac{U_m}{U_{mc}} - 1, \qquad (7)$$

where $I_m$ is the mean current in the measuring circuit.

$U_m$ is the mean voltage across the rectifier when a sinusoidal voltage is being measured ($\alpha \neq \alpha_c$); $I_{mc}$ and $U_{mc}$ the same values for calibrations ($\alpha = \alpha_c$).

The requirement that the effective values of the measured and calibrated voltages must be equal leads to the following condition:

$$U\sqrt{a} = U^x\sqrt{a_c}\ . \qquad (8)$$

In this instance $U^x$ is the maximun value of the calibrated voltage with $\alpha = \alpha_c$.

The error determined by (7) includes both the frequency error and that due to the waveform. The values of these errors and their mutual relationships are determined by the following obvious expressions:

$$F = \frac{U_m U_{mf}}{U_{mc} U_{mf}} - 1 = (F_f + 1)(F + 1) - 1 \simeq F_f + F$$
$$F_f = \frac{U_{mf}}{U_{mc}} - 1; \quad F = \frac{U_m}{U_{mf}} - 1, \qquad (9)$$

where $F_f$ is the frequency error; F is the error due to the shape of the curve; $U_{mf}$ is the mean value of the voltage across the rectifier for $\alpha = \alpha_c$ at the frequency of the measured (nonsinusoidal) voltage.

It will be seen from (9) that for small values of the component errors the total error equals the sum of the frequency error, and that due to the shape of the curve.

From (8) and by obtaining $U_{mc}$ from (3) for $x = 0$ and $\alpha = \alpha_c$, we can derive the total error:

$$F = 2.22 \frac{f(a, x, p)}{\sqrt{a}\ (1 - k)} - 1. \qquad (10)$$

In particular for $x = 0$ and $k = 0$

$$F = 1.11\sqrt{\alpha} - 1. \qquad (10a)$$

By substituting $f(\alpha, x, p)$ by the corresponding expressions it is possible to calculate the relation of the total error to the shape of the curve ($\alpha$) and frequency ($x$).

Figs. 6, 7 and 8 represent such relations for particular cases of aperiodic, critical and oscillatory conditions (the calculated points have been joined by straight lines). According to (9) the total error for $\alpha = \alpha_c = 0.812$ as shown in Figs. 6, 7 and 8 is equal to the frequency error; the variation of the total error with respect to its value for $\alpha = \alpha_c$ represents the error due to the effect of the shape of the curve.

3. The computation results lead to general conclusions on the nature of the effect of inductance of the measuring circuit on the measurement error. In the aperiodic condition (Fig. 6) the frequency error rises sharply with frequency, but the error due to the effect of the shape of the curve decreases a little. In passing from the aperiodic to the critical condition (Fig. 7) the frequency error is almost completely compensated; the error due to the shape of the curve also decreases considerably. In the oscillatory condition (Fig. 8) parameter $p$ can be chosen so that for a given frequency ($x$) the total error remains small when coefficient $\alpha$ varies (i.e., when the shape of the curve changes) in the limits of 0.7-1.0. These conditions only hold, however, for a narrow band of frequency variations. When the frequency is raised, not only does compensation disappear, but the total error actually increases.

The nature of the error curves, represented in a general manner in Fig. 8, is due to transient processes in the measuring circuit, mainly in the inductance. It is easily seen that for certain ratios of the values of $p$ and $x$ the transient process in the interval $\alpha T/2$ (Fig. 5) changes to a very small extent the mean value of the voltage across the rectifier. In the interval of $(1-\alpha)T/2$ the above mean voltage value is, however, increased by the transient process in the inductance thus leading to a decrease in the error in the range of $\alpha < \alpha_c$ (Fig. 8). For $\alpha \to 1$ the duration of interval $(1-\alpha)T/2$ decreases, thus decreasing the effect of the corresponding transient process in the inductance. At the same time the mean voltage across the rectifier decreases in the interval $\alpha T/2$ owing to a decrease in $\alpha$, thus leading to a reduction of the total error in the range of $\alpha \to 1$. It should be noted that when the frequency is raised (increasing x), a reduction in the mean voltage is prevalent in the interval of $\alpha T/2$, which is not compensated by the transient process in the interval $(1-\alpha)T/2$, thus making the total error increase (Fig. 8).

There are good reasons to believe that in the case of complicated rectifier voltmeter circuits (in particular, bridge circuits) the character of the inductance effect will remain the same as the one shown above.

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# MEASUREMENT OF DIRECT AND ALTERNATING CURRENTS BY MEANS OF THE HALL EFFECT

M.E. Mazurov and I.N. Prudnikov

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July, 1960

It is known [1] that if the same alternating current I is passed through a Hall transducer 1 (Fig. 1) and a winding 2 which produces a magnetic field around the transducer the former will act as a square law detector. Hall's voltage in this case can be found from:

$$U_x = kI^2 + kI^2 \cos 2\omega t, \qquad (1)$$

where k is the coefficient of proportionality; $\omega$- the angular frequency of the alternating current; t - time.

It will be seen from (1) that Hall's emf contains a dc component. This component can be measured, for instance, with a millivoltmeter 3 (Fig. 1).

It is clear that the same circuit can be used for measuring direct current, this can be seen from (1) if the angular frequency is assumed to be $\omega = 0$. The advantages of this method consist in the possibility of using it over a wide range of frequencies (Hall's transducer is an almost purely resistive device), a wide range of currents and in the stability of the circuit elements for short overloads.

The defects of the instrument consist of a relatively small dc component of the output emf and of the non-linear relation of the transducer's output emf to the measured current.

In practice, the frequency range of the instrument as shown in Fig. 1 is limited by the induction of the winding which produces the magnetic field. A reduction of winding inductance leads to the lowering of the magnetic field strength, and hence of the value of the dc component of Hall's emf. This also involves a rise in the effect produced by external magnetic fields on the instrument, which then requires compensation.

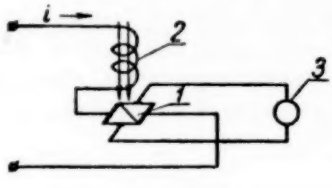


Fig. 1

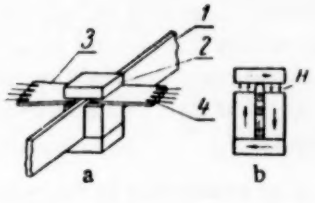


Fig. 2

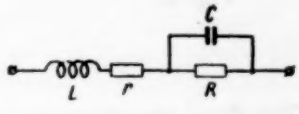


Fig. 3

It can be shown that one of the radical means of decreasing the inductance of the winding for a given value of the magnetic field produced by it, is the use of ferromagnetic cores. Thus the use of a ferromagnetic core in the shape of a toroid, whose mean length is $l_1$ with an airgap of $l_2$ provides a reduction in the inductance of the winding equal to $l_1$ as compared with the inductance of the winding without a core.

On the basis of this condition we made the winding of the instrument of a copper strip 1 (Fig. 2a) through which the measured current is flowing and which is surrounded by a ferrite core 2. The magnetic circuit has two gaps for two Hall transducers. The use of two transducers almost completely eliminates the effect of external magnetic fields. This is due to the fact that the effective magnetic fields in the gaps of the magnetic circuit (Fig. 2b) have the same value but opposite directions. The output leads of the two transducers 3 and 4 are connected in such a manner that their emfs add (Fig. 2a).

For a further extension of the instrument's frequency range, a correcting network is used (Fig. 3) where R and C are its parameters and L and r the electrical parameters of the magnetic system of the instrument. The parameters of the correcting network are chosen from the relation $C = L/R^2$.

On the basis of the permissible frequency error of the expression $\omega L/r$ it is possible to show that the coefficient of expansion of the frequency range due to the correcting network is equal to

$$N = \sqrt[3]{K^2(K+1)\frac{r^2}{\omega^2 L^2}},$$

where

$$K = \frac{R}{r}$$

(it is assumed that $\omega L/r \leq 0.3$).

Computations show that the use of a correcting network provides a manifold extension of the frequency range of the instrument.

The temperature compensation circuit used in the instrument is based on the use of the negative temperature coefficient of the material in Hall's transducer [2].

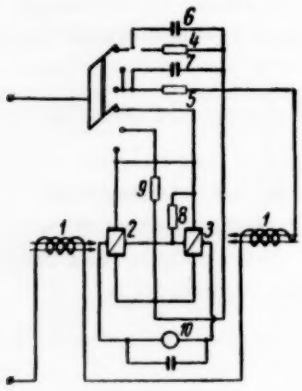


Fig. 4.

In the general circuit (Fig. 4) only part of the winding current runs through Hall's transducer.

The currents in the electromagnets 1 and Hall's transducers 2 and 3 are kept in phase by a parallel connection of carbon resistors 4 and 5. The skin effect is small in such resistors and hence the phasing of the transducers is not altered with rising frequency.

The variation of the instrument measuring range is attained by changing the carbon resistors. Capacitors 6 and 7 together with resistors 4 and 5 form a correcting network.

Owing to the imbalance of the output terminal of the transducer additional zero emfs may appear. In order to eliminate this possibility an additional resistor 8 is inserted between the Hall and current electrodes of one of the transducers. Resistor 9 serves for temperature compensation. The emf at the output of Hall's transducer is measured by means of an indicating instrument 10.

The above instrument was designed as an attachment to the portable microammeter M-95 and tested experimentally. It had the following technical characteristics: measuring ranges 2.5, 5, and 10 amp (with an rms scale); main error 3.5%; frequency range of 0-100 kc; temperature error in the range of 10-40°C not exceeding 1%; its overall dimensions are 145 × 90 × 45 mm; the instrument can withstand a five-fold short overload.

The instrument uses germanium Hall's transducers with a sensitivity of the order of 2 mv/amp · gauss.

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# AN AC COMPARATOR BRIDGE

M.S. Roitman

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 46-48,
July, 1960

Under mass-production conditions it is desirable to be able to determine the deviations from given values of electrical parameters (inductance, capacitance, resistance) with a minimum time delay. For this purpose it is possible to use, with certain limitations, a bridge measuring circuit with phase-sensitive indicating instruments and a voltage-stabilized, fixed-frequency oscillator (see figure).

One arm of the bridge comprises a standard impedance whose value is equal to the nominal value required $Z_{st} = Z_n$ and the other arm consists of the impedance to be measured $Z_x$. The voltage $\dot{U}_{cd}$ at the output of the bridge depends on the deviation $\Delta Z$ of the measured impedance from the nominal value and the bridge supply voltage $U_{1-2}$. If the input impedance of the indicating device is considerably larger than the output impedance of the bridge circuit we have:

$$\dot{U}_{cd} = U_{1-2}\frac{Z_x R - Z_{st} R}{(Z_{st} + Z_x)2R} = U_{1-2}\frac{\Delta r + j\Delta x}{2(2r + 2jx + \Delta r + j\Delta x)}. \qquad (1)$$

The reading of the phase-sensitive indicator can be represented by the projection of the vector $\dot{U}_{cd}$ onto the vector of the reference indicator voltage, i.e., by the value:

$$Re\,U_{cd} = Re\,U_{1-2}\frac{\sqrt{\Delta r^2 + \Delta x^2}}{2\sqrt{(2r+\Delta r)^2 + (2x+\Delta x)^2}}\, e^{-j\,\mathrm{tg}^{-1}\frac{2x+\Delta x}{2r+\Delta r}} \qquad (2)$$

It will be seen from (2) that the instrument reading of one of the components (for instance, x) is affected by the other ($\Delta r$).

The relative error of the reactance X of an impedance with a quality factor Q and a relative variation m of the resistance component r, can be determined from the equation:

$$Re\frac{U_{1-2}(mr + jnx)}{2(2r + mr + jnx + 2jx)} = Re\frac{U_{1-2}(jnx + j\delta_x x)}{2(2r + mr + j\delta_x x + j2x)}$$

or

$$Re\,(j\delta_x Q + jnQ)\, e^{-j\,\mathrm{arctg}\frac{Q(2+n+\delta_x)}{2}} = Re\,\frac{\sqrt{4 + Q^2(2+n+\delta_x)^2}}{\sqrt{(2+m)^2 + Q^2(n+2)^2}}(m + jnQ)\, e^{-j\mathrm{arctg}\frac{Q(2+n)}{2+m}},$$

whence

$$\delta_x = \frac{\sqrt{4 + Q^2(2+n+\delta_x)^2}}{\sqrt{(2+m)^2 + Q^2(n+2)^2}} \cdot \frac{\sqrt{1 + \left[\frac{Q(2+n+\delta_x)}{2}\right]^2}}{Q^2\frac{2+n+\delta_x}{2}} \times$$

$$\times\left\{m\frac{1}{\sqrt{1+\left[\frac{Q(2+n)}{2+m}\right]^2}}+nQ\frac{\frac{Q(2+n)}{2+m}}{\sqrt{1+\left[\frac{Q(2+n)}{2+m}\right]}}\right\}-n.$$

If $Q > 5$, we have

$$\delta_x \simeq m\frac{(2+m)}{Q^2(2+n)}, \tag{3}$$

where

$$m=\frac{r_x-r}{r},\quad n=\frac{x_x-x}{x};\quad Q=\frac{x}{r}.$$

We can determine $\delta$ similarly:

$$\delta_r \simeq n\frac{(2+n)}{d^2(2+m)} \tag{4}$$

($d > 5$), where $d=1/Q=r/x$.

It follows from (3) and (4) that if the ratios of the complex components differ greatly from unity ($r/x < 1/5$ or $r/x > 5$) it is possible to check the impedances by the modulus using an unbalanced bridge with a phase-sensitive indicating instrument.

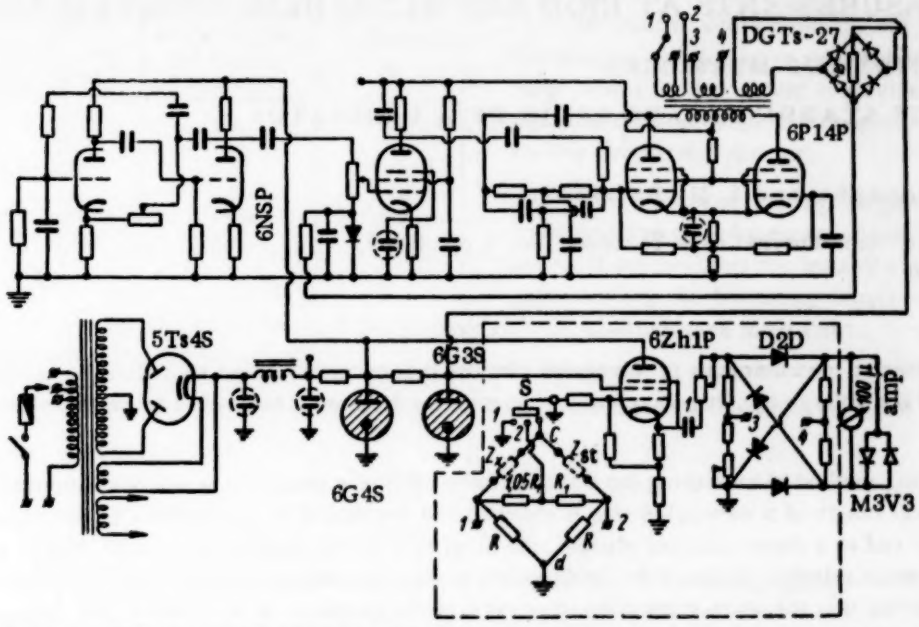
It is obvious that it is possible to determine the deviation of the measured parameter from its nominal value by the unbalance voltage only if the bridge supply voltage $U_{1-2}$ remains constant. The $U_{1-2}$ voltage is stabilized by supplying from one of the transformer windings a high voltage to a rectifier, and comparing the rectified voltage with that of a gas-discharge stabilizer SG3S (see Figure). The voltage difference is fed to the control grid of an amplifier which keeps the output voltage constant. This circuit provides variations of the output voltage of ± 1% when the line voltage changes by ± 10%. In order to prevent feeding to the grid of the amplifier a large positive voltage when the set is being switched on, a nonlinear voltage divider is included in the circuit and is made up of resistors and a crystal rectifier. The small nonlinear distortion factor of the output voltage is ensured by a selective feedback. A cathode follower with a phase-sensitive indicating instrument is connected to the output of the bridge.

The zero drift of the phase-sensitive detector does not exceed 1 mv in 10 hr of continuous working with mains voltage variations of ±10%, even without special selection of diodes. This high stability makes it possible to provide the "Zero adjustment" potentiometer R=1 kilohm with a screwdriver adjustment.

In order to limit the current through the electrical measuring instrument during large unbalances a nonlinear shunt is provided (copper-oxide rectifiers M3V-3).

The sensitivity control (end of scale+ 5%) is attained by the variable resistor R= 470 ohms in position 2 of switch S ("check").

Conclusions. At a frequency of 1000 cps it is possible to check inductances in the range of 50 mh to 50 h and capacitances from 500 μμ f to 0.5 μf and resistors from 300 ohms to 300 kilohms. The instrument provides reading of deviations of the measured parameter from its nominal value on a scale of ± 5% with an error less




than 0.5% and on a ± 20% scale with an error of the order of 1.5% with a line voltage variation of ± 10%. The errors are quoted for a possible dispersion of the effective resistance by ± 20% and linear impedances with a quality factor Q = 10.

The range of impedance measurements can be considerably extended if a provision is made for changing the frequency of the supply voltage.

# MEASUREMENTS AT HIGH AND ULTRAHIGH FREQUENCIES

## AN INSTRUMENT FOR MEASURING THE VOLTAGE STANDING-WAVE RATIO OF A GENERATOR

V.I. Pronenko and L.N. Bryanskii

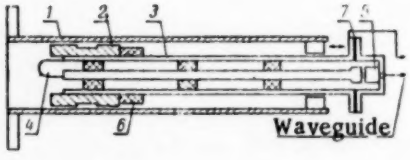
Translated from Izmeritel'naya Tekhnika, No. 7, pp. 48-49, July, 1960

For many precise measurements in waveguide circuits, it is necessary either to match the generator to the required value of the voltage standing-wave ratio or to measure it in order to be able to evaluate the error of measurements.

The following method of measuring the standing-wave ratio of a generator is the most commonly used. When the electrical length of a waveguide line is changed and one end of it is connected to the measured generator and the other end to a short-circuited plunger, the amplitude of the standing wave will change owing to variations in the phase relations between the fundamental and the secondary waves reflected from the generator. It can easily be shown that the voltage standing-wave ratio of the generator is equal for a root-mean-square characteristic of the receiver to:

$$V.S.W.R_G = \sqrt{\frac{U_{max}}{U_{min}}}, \quad (1)$$

where $U_{max}$ and $U_{min}$ are the maximum and minimum voltages in the line, measured in planes equally distant from the short-circuit while the electrical length of the line is changed.




1) Waveguide; 2) contactless plunger; 3) coaxial line; 4) coupling loop; 5) detector; 6) absorber; 7) blocking capacitance.

Normally for measuring the voltage standing-wave ratio of generators a measuring line is used with a movable short-circuiting plunger. By placing the plunger in various positions and adjusting each time the probe of the measuring line to coincide with the standing-wave antinode, the values of $U_{max}$ and $U_{min}$ are determined and the generator voltage standing-wave ratio calculated. The measurement normally lasts 2-3 min and the matching of the generator 15-30 min.

In order to simplify and speed-up the measurement of the generator standing-wave factor it is necessary to vary the electrical length of the line between the generator and the probe, and keep at the same time the length between the probe and the short-circuit constant. This requirement is met by using a phase shifter with a probe head [1], or a phase shifter with a special mismatched detector section [2]. However, high quality phase shifters with a small standing-wave ratio of their own are relatively difficult to make and are large even at the lower end of the centimeter range.

In this part of the range it is advisable to use another instrument, just as simple (see Figure), which consists of an adjustable short-circuiting contactless waveguide plunger, along whose axis of symmetry a hole is made with a diameter below the critical value. A length of coaxial line is fixed to this hole and terminated at one end by the coupling loop and at the other by a wide-band detector chamber. The tube length inside the body of the plunger (from its butt to the coupling loop) serves as a cut-off attenuator. Its attenuation can be varied by moving the coaxial line with respect to the plunger.

The attenuation adjustment makes it possible to choose the required coupling between the detector chamber and the waveguide cavity for various generator power levels.

| Wave-length, cm | V.S.W.R. according to a line | V.S.W.R. according to the above instrument | Difference, % |
|---|---|---|---|
| 3.2 | 1.015 | 1.01 | 0.5 |
| 3.2 | 1.03 | 1.03 | — |
| 3.2 | 1.24 | 1.26 | 1.6 |
| 3.2 | 1.56 | 1.54 | 1.4 |
| 12 | 1.02 | 1.015 | 0.5 |
| 12 | 1.35 | 1.36 | 0.8 |

In order to avoid errors caused by a reduction of the plunger standing-wave ratio (when measuring large ratios) the instrument is provided with a restriction which prevents the coupling loop from protruding outside the plunger.

The error in measuring the generator voltage standing-wave ratio by means of this instrument depends (if one neglects the instability of the measured generator and the indicating instrument) on the following two main causes: the finite value of the plunger voltage standing-wave ratio and its variation when the plunger is displaced along the waveguide.

The effect of the plunger standing-wave ratio can be evaluated from the precise formula:

$$\frac{U_{max}}{U_{min}} = \frac{1+|R_G||R_p|}{1-|R_G||R_p|}, \qquad (2)$$

where $R_G$ is the reflection factor of the generator; $R_p$ is the reflection factor of the plunger.

Whence the relative error in measuring the voltage standing-wave ratio is

$$\delta_k = \frac{2|R_G|(1-|R_p|)}{(1+|R_G|)(1-|R_G||R_p|)}. \qquad (3)$$

It is obvious that the error decreases with a decreasing $|R_G|$ i.e., with a smaller standing-wave ratio of the generator, thus making it possible to match the generator with great precision.

The value of the error of measurement which is due to the change in the plunger standing-wave ratio produced by the plunger displacement can be approximately taken as the value of the generator standing-wave ratio attainable by matching.

The above instrument was made of waveguides with cross sections of 23 × 10 mm and 72 × 34 mm. Its standing-wave ratio was equal to about 20-25, which corresponds to an error of 3% due to the finite value of the plunger standing-wave ratio for a generator ratio of 2.0 and an error of 0.6% for a generator ratio of 1.1.

The minimum measured standing-wave ratio of the generator was 1.015 (the error due to the variation in the plunger standing-wave ratio was 1.5%). Thus the total error is about 3.5% for a standing-wave ratio of 2.0 and about ± 1.7% for a standing-wave ratio of ≤ 1.1; the measuring time does not exceed 15-20 sec.

In addition to calculations, the measuring results obtained by means of a measuring line and this device were compared. The comparison table is appended.

Conclusions. The comparison results confirm the relatively high accuracy of measurement of the standing-wave ratio by means of the above instrument.

The instrument can also be used for matching the generator when its potput is insufficiently decoupled and there is a possibility of the results being distorted by the reaction of the adjustable plunger on the generator. For avoiding this reaction another hole should be made in the body of the plunger, and an absorbing sliding wedge placed in it. The protruding wedge lowers the standing-wave ratio of the instrument and decreases its effect on the generator. When the instrument is used for accurate measurements of the standing-wave ratio the absorber is pushed inside the plunger and produces hardly any effect on the operation of the instrument.

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# RAISING THE SENSITIVITY OF THE OSCILLOGRAPHIC METHOD OF DISCOVERING DISTORTIONS IN SINUSOIDAL VOLTAGES

Z.B. Shvaya

Polish People's Republic

Translated from Izmeritel'naya Tekhnika, No. 7, p. 50,
July, 1960

A direct observation of a voltage waveform on a screen of a cathode-ray oscilloscope provides the possibility of discovering deviations from the sinusoidal shape, if the nonlinear distortion factor is not less then 2-5%.

In order to observe smaller distortions it is advisable to connect to the oscilloscope input a differentiating RC network (Fig. 1) which has a higher transfer constant for the fundamental than the higher harmonics. This will increase the nonlinear distortion of the voltage fed to the oscilloscope as compared with that supplied to the RC network, and will make it possible to observe smaller distortions than otherwise would be possible.

In order to make the operation of the RC network effective, it is necessary to make the reactance of capacitor C at the fundamental frequency about 1/10 of the resistance of R. It is obvious that when this condition is fulfilled, the relative content of the second harmonic will increase at the output of the RC network by a factor of about 2 as compared with its content at the input of the network. The content of the 3rd harmonic is trebled, etc. for the first few harmonics.

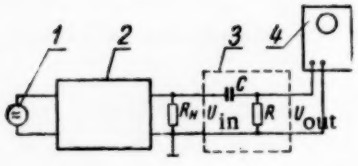


Fig. 1. 1) Sinusoidal voltage generator; 2) amplifier; 3) RC network 4) cathode-ray oscilloscope.

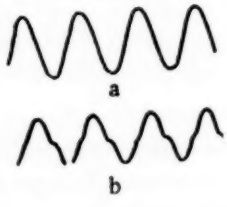


Fig. 2. Oscillograms of the voltage at the RC network terminals. f = 1000 cps; C = = 0.01 μf; R = 500 ohms; a) at the input terminals; b) at the output terminals.

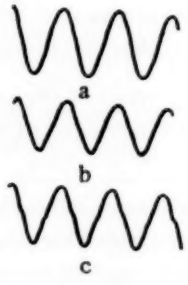


Fig. 3. Oscillograms of the voltage at the RC network terminals. a) at the input, f = 1000 cps; b) signal from a after passing through the RC network C = 0.01 μf; R = 4 kilohms; τ = 40 μsec; c) ditto with C = 0.01 μf; R = 500 ohms; and τ = 5 μsec.

Figs. 2 and 3 show how distortions imperceptible to the eye are converted by the RC network to easily noticeable shapes.

# MEASUREMENTS OF MASS

## A SEMICONDUCTOR CAPACITATIVE DEVICE FOR SIGNALLING THE LEVEL AND SEPARATION OF PHASES

B.Z. Votlokhin

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 50-51, July, 1960

In recent years, level measuring and signalling devices of a capacitative type have been developed on the basis of registering capacitance changes of special transducer-probes which consist of capacitor normally formed by two plates or coaxial cylinders.

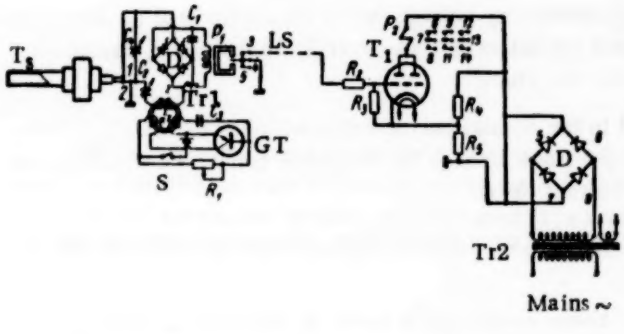


Fig. 1

Fig. 2

For measuring the level of electrically conducting liquids or loose materials transducers in the shape of a metal probe are used, with the probe insulated by a thin dielectric layer (teflon, viniplast etc.). The transducer is placed in the reservoir or bunker where the level of the electrically conducting media is to be measured. One of the capacitor electrodes is formed by the metal probe and the other by the electrically conducting medium. By measuring the variation of the transducer capacitance the required level is determined.

The level of the dielectric liquid or loose materials is determined by the variations of the capacitances of the transducer placed in the medium.

The electronic level signalling device type ESU-1 is fairly widely used in industry.

Side by side with its positive properties (simplicity of construction, reliable operation) it has considerable defects, it required line supplies and the necessity of extending the supply cables to the power pack which is near the transducer. This transducer cannot be widely used in oil and chemical plants owing to its construction which is not explosion-proof.

Below we describe a transistorized, capacitative, level and phase separation signalling device PESU-1 which was developed by us for continuous operation from a single dry cell type ZSL-30 for 1500-2000 hours.

The signalling device consists of three similar channels, intended for measuring the low "danger", mean and top "danger" levels in a tank, bunker of other container. All the three channels are identical and, therefore, it is sufficient to examine the work of one of them.

The channel (Fig. 1) consists of a capacitative transducer Ts, a blocking oscillator, which comprises a germanium transistor $GT_1$, a toroidal ferrite transformer $Tr_1$, a polarized relay type RP-5, a bridge detector incorporating germanium diodes $D_1$-$D_4$ and adjusting capacitors $C_2$ and $C_4$.

The blocking oscillator consumes 15 ma at 1.5 v from one of the dry cells B type ZSL-30 and produces oscillations at 20 v, 25 kc.

When the supply voltage is connected to the emitter of transistor $GT_1$ by means of switch S the voltage rises owing to the charging of the capacitor $C_3$. The rise of the emitter voltage produces a current rise in the

emitter-base circuit and a corresponding current in winding III of transformer $Tr_1$. This current rise produces an increased voltage in winding II and an additional rise in the emitter voltage. This increases the current in the emitter-base circuit, raising the voltage in winding III, etc. When the collector current attains its stable value its rate of increase drops together with the emf induced in winding II.

The drop in the emitter voltage produces a drop in the collector voltage. This process, similarly to the rising voltage effect, has an avalanche nature and continues until there is no current flowing through the collector. At this instant there occurs a sudden change in the electromagnetic field of the transformer inducing in winding III an emf which is proportional to the rate of change of the current and the inductance of the winding. Thus after the stopping of the current there appears on the collector a negative voltage overshoot which raises considerably the supply voltage. At the same time a positive overshoot appears in winding II and charges capacitor $C_3$. Thus the circuit is returned to its original condition and the process begins all over again.

The blocking oscillator produces a voltage of a certain value and frequency, which is determined by the parameters of the circuit, and with an appropriate selection of these parameters the voltage approaches a sinusoidal shape. From the step-up winding I of transformer $Tr_1$ the voltage is fed through capacitor $C_2$ bridge $D_1$-$D_4$ to transducer Ts. Since the bridge and the transducer are connected in series and the capacitance of the transducer is consideraly less than a tenth of capacitor $C_2$, the alternating voltage fed to the bridge will be determined by the value of the transducer capacitance. Thus for small variations of transducer Ts capacitance, caused by variation of the level, the voltage across bridge $D_1$-$D_4$ will also change.

Relay $P_1$ is adjusted to have its contacts 4-5 closed in the normal position (biased adjustment). The relay will operate (closing contacts 3-4) when a current ot 650 $\mu$a flows through its two series-connected windings and release when the current drops to 640 $\mu$a (disconnecting contacts 3-4).

The relay operates reliably with a change in the transducer capacitance from 103 $\mu\mu$f (closing of contacts 3-4) to 101 $\mu\mu$f (opening of contacts 3-4).

In order to adjust the transducer capacitance to the above values use is made of capacitor $C_4$ and $C_2$.

The transducer is placed in the tank and connected by means of a short coaxial cable (0.5 - 1 m) to the transistor unit. The remote signalling of the level changes is accomplished by means of a dispatcher's desk with which the primary signalling devices are connected by a single conductor line LS. The dispatcher's desk contains an electronic, grid-controlled, intermediate relay (tube $T_1$). Normally the grid of tube $T_1$ (6N15P) is at zero potential. The electromagnetic relay $P_2$ (type RPN) is operated since an anode current is flowing through the tube.

When the level changes relay $P_1$ contacts 3-4 close and connect the control grid of tube $T_1$ to ground through resistor $R_2$. This operation connects the negative voltage developed across resistor $R_5$ to the grid of the tube and blocks it. The anode voltage of tube $T_1$ is cut off, relay $P_2$ deenergizes and closes contacts 6-14 connecting the signalling and control circuits. The germanium bridge rectifier $D_5$ - $D_8$ and transformer $Tr_2$ are common to all the three channels.

The capacitative transducer transducer (Fig. 2) consists of a metal rod 1 inside a teflon jacket 2. The rod is connected by means of a coaxial cable 3 to the transistor unit. The transducer is fixed to the wall of the tank or bunker by screwing its frame 4 into a special socket. The internal cavity of the transducer and the leading-in coaxial cable are hermitically sealed by means of gland unit 5 and 6.

These transducers have been extensively tested in measuring levels and boundaries of phases of various conducting and dielectric liquids (oil products and acids) and loose materials. For measuring the level of liquids with good dielectric properties it is necessary to place on the teflon jacket a metal perforated sleeve, leaving a certain gap between them and connect the sleeve to the body of the transducer.

The signalling devices were also tested with pneumatic transmitting channels. The electrical circuit of the device remained unaltered. The moving armature 4 of the polarized relay $P_1$ was extended and served as a valve for controlling the air pressure in the central operning of a throttle. When the level changes, the operation of relay $P_1$ closes the throttle and sends a pulse to the controlling valve or a manometric indicating instrument.

Conclusions. The above signalling device can be used for automatic filling or emptying of tanks or bunkers, the discharge of by-products or seeping water.

# ESSAYS AND REVIEWS

## HALL'S EFFECT AND ITS APPLICATION IN MEASUREMENT TECHNIQUES

A.M. Ilyukovich

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If a thin semiconductor plate of thickness h is placed in a magnetic field of induction B and a current I is passed through it (Fig. 1), a voltage $U_h$ will arise at the edges of the plate. This phenomenon is known as Hall's effect and voltage $U_h$ as Hall's voltage. Hall's voltage is equal to:

$$U_h = \frac{K_h}{h} BI, \qquad (1)$$

where $K_h$ is Hall's constant

Hall's effect has been known for a long time, but its wide technical application has only developed recently in conjunction with improved production of semiconductors. Germanium, mercury selenide and telluride, arsenical and antimonial indium, etc., are used [1] as materials for Hall's transducers. Below we give a list of possible uses of Hall's effect in measurement techniques and quote its practical applications.

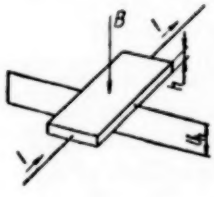


Fig. 1

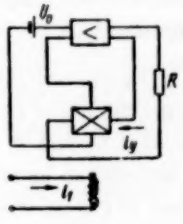


Fig. 2

Multiplication of two or several quantities. Hall's voltage is proportional to (1) the product of induction B and current I, therefore it is possible to obtain by means of a Hall transducer the product of any two quantities (and with a cascade connection of transducers of any number of quantities) which can be converted into ac or dc signals proportional to their values.

Obtaining reciprocal values. The circuit for obtaining reciprocal values is shown in Fig. 2. The magnetic field in which the transducer is placed is produced by current $i_1$. The transducer controlling circuit is fed through resistor R by current $i_y$ from the amplifier whose input is supplied with the difference of the reference voltage $U_0$ and voltage $U_h$ from the output of the transducer. If the gain of the amplifier is sufficiently high, voltage $U_h$ will rise in this circuit until it becomes equal to $U_0$ Then the following relationship will hold [2]:

$$U_h = ci_y i_1 = U_0 = \text{const}. \qquad (2)$$

Whence the output current of the amplifier is:

$$i_y = cU_0 \frac{1}{i_1}, \qquad (3)$$

i.e., it is inversely proportional to current $i_1$ in the excitation winding of the transducer.

Division of two quantities. In combining the circuits for multiplying two quantities and obtaining a reciprocal, it is possible to design a circuit [2] for dividing two quantities (Fig. 3). The amplifier output current $i_y$ is coupled with current $i_1$ by relation (3) in order to obtain a reciprocal, and then it feeds the controlling circuit of the Hall transducer whose field is provided by current $i_2$. Then the output voltage $U_2$ of the transducer will be:

$$U_2 = c I_y I_2 = c^2 U_y \frac{i_2}{i_1}, \qquad (4)$$

i.e., proportional to the ratio of currents $i_2$ and $i_1$.

As an example of the application of Hall's transducer for this purpose one can cite the testing of instrument current and voltage transformers (both for phase and value) by means of the differential method [3] and obtaining a direct reading of their error.

Power measurements. When Hall's transducer is connected as shown in Fig. 4 the dc component of Hall's voltage $U_h$ is proportional to the power dissipated in load Z. By an appropriate connection it is possible to measure both the effective, wattless or combined power. By using several Hall transducers (one for each phase) and adding their output voltages, it is possible to measure the effective, reactive and combined power of a three-phase circuit. Detailed information on measurements of power in low-frequency circuits is given in [4]. Single-phase and three-phase wattmeters, whose error does not exceed 0.8% over a wide range of temperatures, are also described in [4]. In [5, 6] the principle of measuring power by means of Hall's effect at frequencies up to 3000 Mc is described.

Great advantages are obtained from the application of Hall's transducers when oscillographing power, for instance, in the investigation of dynamic processes in single-and especially three-phase machines [7].

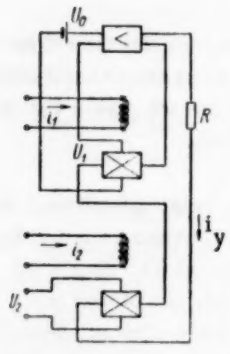


Fig. 3

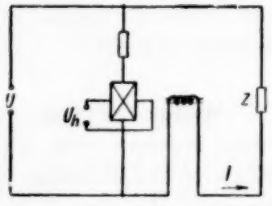


Fig. 4

Measurement of the torque of motors. The torque of dc motors is equal to

$$M = c\Phi I_a,$$

where $\Phi$ is the magnetic flux in the air gap; $I_a$ - the armature current.

By placing Hall's transducer in the air gap of the machine and passing through it a current proportional to that of the armature, we shall obtain at the transducer output a voltage proportional to the torque of the machine [7, 8]. This method can be used for obtaining starting characteristics of motors and also for an automatic control of the torque of motors.

Measurements of constant and variable magnetic fields. If a Hall transducer is placed in a magnetic field and a constant current is maintanined through the transducer, Hall's emf will be proportional to the strength of the field. The advantages of this method consist in the simplicity of the instrument, direct reading of the field strength, the possibility of easily varying the range of measurements (by changing the current flowing through the transducer), the linearity of the scale, small dimensions of the transducer (thus making it possible to measure accureately the magnetic field strength variations in space), etc. This led to the wide use of this type of instrument [9-11]. The error of these instruments does not exceed 1-1.5%.

Measurement of large direct and alternating currents. When currents of the order of thousands and tens of thousands of amperes are measured, the use of ordinary shunts involves considerable difficulties. This problem can be solved very simply by using Hall's transducers. The transducers are placed fairly close to the bus bars carrying the current, i.e., in the magnetic field of the current to be measured or in the airgap of measuring tongs. Instruments of this type are already being used. The instrument described in [12] for measuring currents up to 100 amp has an error not exceeding 0.2%.

Conversion of a direct to an alternating current. If the magnetic field of the transducer is provided by an alternating current of a constant value and frequency f, and a certain direct current I is made to flow through the transducer, its output voltage will be proportional to current I [13] and will vary with frequency f. It is shown in [1] that the conversion factor of such a device, i.e., the ratio of the output alternating emf to the direct voltage at its input can be made sufficiently high (of the order of 20%).

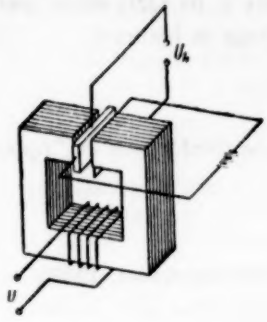


Fig. 5.

Linear detection of alternating currents. By establishing a transducer magnetic field with a constant alternating current, i.e., $B=B_0 \sin \omega t$, where $B_0 = \text{const}$ and by passing through the transducer an alternating current of the same frequency $I=I \sin(\omega t - \Theta)$ we shall obtain a transducer output voltage of

$$U_h = \frac{K_h}{h} B_0 I_0 \sin \omega t \sin(\omega t - \Theta) = \frac{K_h}{2h} B_0 I_0 \cos \Theta - \frac{K_h}{2h} B_0 I_0 \cos(2\omega t - \Theta). \quad (6)$$

The value of the dc component of this voltage is proportional to the amplitude of the alternating current ($I_0$) passing through the transducer, it also depends on the phase difference between I and B, i.e., this detector is phase sensitive. A device of this type is described in [14].

Root-mean-square detection of alternating currents. Let the transducer's magnetic field be provided by the same alternating current as the one passing through the transducer, i.e., $I=I_0 \cos \omega t$, $B=kI_0 \cos \omega t$. Then the voltage at the output of the transducer will be

$$U_h = \frac{K_h}{h} K I_0^2 \cos^2 \omega t = \frac{K_h k}{2h} I_0^2 + \frac{K_h k}{2h} I_0^2 \cos 2\omega t, \quad (7)$$

i.e., the dc component of the voltage is proportional to the square of the current amplitude [14]. The use of such a detecting device is suitable for determining the value of $\int i^2 dt$ which characterizes fuses [15]. In [16] the use of Hall's square law detector for measuring alternating currents at frequencies up to 100 kc is described.

Frequency spectrum analyzer. If the magnetic field of the transducer is supplied from a sinusoidal source and the current through the transducer is nonsinusoidal, it is possible to detect linearly the harmonics of this current by making it coincide with the altered frequency of the magnetic field. By measuring the dc component at the output of the transducer it is possible to determine in sequence the values of all the harmonic components of the current flowing through the transducer. It was possible to discover harmonics amounting to 0.01% of the total measured amplidute by using a model of such an analyzer [14]. A mirror glavanometer with a sensitivity of $1.5 \cdot 10^{-8}$ amp/division was used in these measurements.

Voltage and power amplification of dc and ac signals. The schematic of an amplifier based on Hall's effect is shown in Fig. 5. A thin Hall transducer is placed in the gap of a high-permeability core. The magnetic field is provided by voltage U, which it is required to amplify. The controlling circuit of the transducer is fed from a constant dc supply. Hall's voltage $U_h$ is fed a matched load. An experimental amplifier of this type [27] with an arsenical indium transducer provided power gains of 5.

Alternating current generator. If in the circuit of Fig. 5 a positive feedback is introduced between the output and input of the device, Hall's amplifier becomes converted into a generator of alternating currents. The advantages of this generator consist in its simplicity, small size and long life.

Measurements of pressure. The application of Hall's transducer for converting mechanical values to electrical ones and in particular for measuring pressure is examined in [18]. The measured pressure reacts on an elastic plate placed in the magnetic field. A Hall transducer is fixed to the plate. Under the effect of pressure the plate bends and the angle between the plane of the transducer and the direction of the field changes. As the result of this Hall's voltage changes. It appears that in a similar manner it is possible to convert other mechanical quantities such as linear displacement, rotation angle, etc into electrical values.

Side by side with Hall's effect, that of Gauss is beginning to be used in measurement techniques. Gauss' effect follows from Hall's effect and consists in the drop of the voltage across the semiconductor transducer under the effect of the magnetic field. In [19] this effect is analyzed in detail and a wattmeter based on the effect is described. Transducers based on the Gauss effect are simpler than those using Hall's effect, since they lack the current collecting devices required in Hall's transducers which are difficult to balance for voltage. It is, therefore, possible that Gauss transducers will in certain cases replace Hall's transducers.

The listing of the instances when Hall's transducers can be used in measurement techniques covers only a small portion of all their possible applications. The development in this sphere is only at its early stages and it is possible to expect the extent to which Hall's effect is applied in industry will continue to increase.

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## INITIATION OF INDEPENDENT INVESTIGATIONS

M.S. Bril'

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 55-56,
July, 1960

Side by side with fulfilling the plans in supervising the condition of measures and measuring instruments and enforcing the standards and technical specifications, the regional State Inspection Laboratories of the Ukrainian SSR periodically initiate independent investigations and checks.

Under the term independent investigations, we understand a thorough inspection of several plants and organizations of any systems or of similar workshops in different plants according to a narrow program.

The independent investigations and checks are aimed at improving measurement equipment and methods of testing of raw materials and finished products, at improving the utilization of raw materials, electrical energy, gas, water, at raising the quality of production, at improving the working conditions of the personnel, etc.

The results obtained in checking several plants and organizations provide the opportunity of generalizing the data and compiling a sufficiently full account of the conditions prevailing in any system or group of plants, trust, or trading association.

In the work of independent inspections the laboratories welcome the participation of the local press, social inspectors, workers in the quality control, personnel of scientific research institutes, consumers of the products, and workers of the anti-fraud departments,

The data thus obtained is ususally brought to the notice of party, Soviet and industrial organizations as well as the press.

On the request of the Republican Administration, the Laboratories of the Ukr. SSR checked the voltage and frequency of rural power stations, and the condition of their measuring equipment. In the course of this inquiry, it was established that the voltage is below the nominal value (150 - 170 v instead of 220 v), and the frequency is unstable, thus preventing the consumers from using in a normal manner their motors, domestic appliances, television sets and radio receivers. In several instances incorrect operation of generators, wiring of meters, the use of wrong measuring instruments, lack of registration of reactive currents and other serious failings, were discovered.

Generalized results of these checks were communicated to the regional offices of the "Sel'énergo", the Regional Soviet Executive Committees and the Minsitry of Agriculture of the Ukr. SSR. The Principal Administration for Electrificiation of the Ministry of Agriculture of the Ukr. SSR issued, on the basis of this material, an instruction outlining the steps to be taken in order to correct these defects.

In fulfilling the suggestions of the State Inspection Laboratories and the order of the Ministry, the "Sel'énergo" sent to the rural power stations crews of mechanics and specialists who tested the generators, corrected the defects in their work, withdrew from use the defective measuring instruments and checked the accuracy of power consumption meters.

The personnel of the Zaporozh'e State Inspection Laboratory in conjunction with the Zaporozh'e Engineering Institute checked the quality of metal smelted in auxiliary shops in several plants of the city.

In the casting department of the repair shop of the Dneper Aluminum Plant the chemical composition of smelted steel was below standard in the content of silicon, manganese and carbon.

In the casting shop of the transformer plant, the mechanical properties of gray iron castings were not tested, despite the existence of the required equipment; in the titanium-maganese plant the chemical analysis of pig iron was made only by means of sample testing, there were no technical certificates for the castings, and grades of cast iron specified on drawings were altered.

The data of these checks was submitted to the Zaporozh'e Council of National Economy, and the administrations of the plants received corresponding instructions.

In a repeat check of these establishments it was found that the quality of their castings had improved, a systematic control of smelting was established and the chemical properties of pig iron were checked systematically.

The Kiev State Inspection Laboratory of Measurement Equipment in conjuction with the editorial board of the newspaper "Vechernii Kiev" investigated the condition of water measurements and the accuracy of water rates.

The checking of domestic water meters, which record the consumption of individual houses or groups of small houses, revealed their unsatisfactory technical condition. Of the 13 meters subjected to sample tests only two were found to be satisfactory.

The newspaper "Vechernii Kiev" carried an article on the results of this investigation. In addition an open letter to the City Soviet was published in this paper, on the correction of the water rate charges.

On the suggestion of the State Inspection Laboratory the "Vodosbyt" office improved its control over the condition of water meters, made the dates of their checking more frequent, increased the stock of water meters and improved their repairs.

The Odessa State Inspection Laboratory initiated an independent inspection of the quality of production, condition of the equipment and technique of measurements at the plants of the regional administration of local industry which made synthetic materials and produced articles from them.

Owing to the lack of laboratory equipment and measuring instruments at these plants no laboratories existed and no checking of the basic physico-mechanical properties of the products was carried out nor a chemical analysis of the raw materials made. The personnel of the Technical Control Divison inspected the finished articles in an unsatisfactory manner and exaggerated the grade of its quality.

As the result of energetic measures taken by the State Inspection Laboratory in eliminating these defects the quality of production was greatly improved.

For instance the chemical plant introduced a new method of making textolite which provides a complete coverage of the fabric surface with the compound, it repaired the block for printing scales, the imprint of the scales on rules and squares has become clearer, and the mechanical properties of the finished products are now being checked on tensile strength measuring machines.

A repeated check of phonograph records at the plastics manufacturing plant showed that the records were up to the specified standard.

In the electrical installation equipment shop of this plant a new testing bench was set up for testing overheating, overload, and mechanical and electrical strength of the equipment.

The Dnepropetrovsk, Kherson, Chernovitsky, L'vov, Lugansk and other Laboratories of the Ukrainian SSR also initiated independent inspections.

Inspection and checking with a certain object in view help to improve measurement techniques, raise the authority of State Inspection Laboratories of Measuring Equipment and are undoubtedly beneficial to our national economy.

# THE CONTROL AND MEASURING INSTRUMENT LABORATORIES AND THE TECHNICAL INSPECTION OF THE MEASURING EQUIPMENT

N.M. Ershov

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 56-57,
July, 1960

In several Stanislav and Transcarpathian region establishments the measuring equipment often remains between State inspections in an unsatisfactory condition, since the Control and Measuring Instrument (KIP) Laboratories only check, adjust and repair in the main, instruments and measures of one type. It is time to concentrate in the KIP Laboratories the supervision over all the measuring equipment, but this is connected with organizational and material difficulties. However the State Inspection Laboratories of Measuring Equipment could train the personnel of the KIP Laboratories. Then this trained personnel could supervise the measures and measuring instruments and instruct other workers in checking techniques.

Editorial note. N. M. Ershov is correct in stressing the necessity of a unified control over the condition of the measuring equipment at plants and of making the laboratories supervise types of equipment which they were not intended to do originally.

At present the Committee of Standards, Measures and Measuring Instruments has before it a draft regulation on central factory laboratories which provides for the unification of all the plant test laboratories into a single central laboratory which would ensure supervision of the whole of the measuring equipment of a plant.

If the amount of work in certain spheres of measurement is small these sections are not to be organized in the central laboratory; the checking of instruments of such types will be made by the area laboratories of the Councils of National Economy under contract or else the instruments will be submitted for State inspection. The Central Laboratory nevertheless will exercise supervision (correct use, timely checking, etc) over instruments of such types.

# INFORMATION

## THE ALL-UNION SCIENTIFIC AND TECHNICAL CONFERENCE ON AUTOMATIC GAS ANALYZERS

B.I. Rabinovich

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 57-58, July, 1960

An All-Union Scientific and Technical Conference on Automatic Gas Analyzers was organized in Leningrad on May 9 to 14, 1960 by the regional administration of the Scientific and Technical Society of the Instrument Making Industry and the Special Design Office (SKB) of Analytical Instrument Making of the Academy of Sciences, USSR. The Conference was attended by more than 600 delegates representing over 230 organizations. Over 80 papers and reports were read at the Conference.

V.A. Pavlenko (SKB of Analytical Instrument Making of the Acad. Sci. USSR) stressed in his paper the special importance of gas analyzers in total automation of production processes in the main branches of our national economy. Many of our gas analyzers are completely up-to-date, but they are produced in insufficient numbers in the Soviet Union and their production must be drastically increased.

N. Ya. Fest's paper (OKB for Automation of the State Committee for Chemistry of the Council of Ministers of the USSR) dealt with the technology of automatic gas analyzers in connection with the rapid development of the chemical industry. The specific requirements in connection with the processing of gas, liquid and solid products, which are often corrosive, explosive, or poisonous, makes it necessary to use special measuring instruments and means of automation. This requirement demands the application of the most promising methods of analysis, such as radioactive radiations, radiospectroscopy, electronic, paramagnetic and nuclear resonance, spectral analysis, chromotography, and the use of computers for analyzing multicomponent gas mixtures.

In connection with the diversity of gas analyzers due to the conditions of their use, N.Ya. Fest noted the necessity of the most extensive normalization and standardization of gas analyzers.

B.R. Tarasov (D.I. Mendeleev All-Union Scientific Research Institute of Metrology, VNIIM) dwelt on the basic methods for calibrating and checking automatic gas analyzers. The basis task in checking automatic gas analyzers should consist of determining their metrological, constructional and other parameters, the most important of which are errors. Only gas analyzers which have passed these tests should be submitted for inspection. In view of the numerous methods of analysis, types of instruments and a large variety of gas mixtures both with respect to their composition and degree of concentration the checking of gas analyzers presents many difficulties. It is therefore advisable that the development of the reference equipment for checking gas analyzers and the compiling of the corresponding specifications should be undertaken jointly by the metrological institutes and the interested organizations.

V.I. Loshak (All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments, VNIIK) described the basic results of the State testing of automatic gas analyzers carried out by the Committee. The author paid special attention to the construction and technological completeness of the experimental models in connection with the requirement of comparing them with instruments developed by other organizations in order to select the best for mass production.

In his paper D.L. Orshanskii (SKB of Analytical Instrument Making of the Acad. Sci. USSR) characterized modern gas analyzer production abroad. The production of gas analyzers in certain capitalist countries, especially the USA and the FGR, is highly developed. Thus in the USA automatic gas analyzers are produced by 130 companies, in Britain by 40 and in France by 15 companies. The production in these countries is distinguished by the variety of instruments produced and the speedy response to the requirements of users. However standardization of gas analyzers is lacking not only on an international but even on a national scale. Neither is there a generally accepted system for evaluating gas analyzers or methods for testing them.

The paper read by A.K. Osokina (Planning and Design Office [PKB] of the State Committee for Automation and Engineering of the Council of Ministers of the USSR) dealt with requirements of automatic gas analysis.

The prospects of using in Medicine gas analyzers based on physical methods were described by A.P. Pistsov (All-Union Scientific Research Institute for Medical Instruments and Equipment).

V.A. Nikitin (Giprogaztopprom) dwelt on the basic requirements of automatic analyzers used in the oil by-products industry.

The utilization of quality analyzers in production control systems in the nitrogen manufacturing industry was described by L.I. Zhukovskii (OKB for Automation of the State Committee for Chemistry of the Council of Ministers of the USSR).

A review of the development of Soviet thermomagnetic gas analyzers was presented by D.M. Sheinin (SKB of Analytical Instrument Making of the Acad. Sci. USSR). He noted that Soviet thermomagnetic gas analyzers are of a better quality than foreign types; for instance the oxygen gas analyzer MN 5106 was awarded a gold medal at the Brussels exhibition.

D.I. Agaikin (Institute of Automation and Remote Control of the Acad, Sci. USSR) dealt with compensation-type oxygen magnetic gas analyzers. The compensation method provides a higher sensitivity for the instruments.

The details of magnetic gas analyzer designs were described by M.K. Yarmak (OKB for Automation of the State Committee for Chemistry of the Council of Ministers of the USSR), L.S. Dvornik (Central Planning and Design Office of the "Sevzapmontazhavtomatika" trust) and I.B. Kaplunov (F.E. Dzerzhinskii All-Union Thermotechnical Institute).

Thermal methods and instruments were described by N.S. Matrosova (OKB for Automation of the State Committee for Chemistry of the Council of Ministers of the USSR), Ya.M. Itkin, F.M. Kholov and M.T. Borok (SKB of Analytical Instrument Making of the Acad. Sci. USSR) I.G. Perevezentsev (Ural Scientific Research Chemical Institute) and E.F. Karpov (State Planning and Design Institute "Giprougleavtomatizatsiya").

Gas analyzers based on an electrical method were described by A.N. Blazhenova and N.K. Filatova (OKB for Automation of the State Committee for Chemistry of the Council of Ministers of the USSR), E.T. Alitovskii (SKB of Analytical Instrument Making of the Acad. Sci. USSR) and E.V. Kasatkin (L.Ya. Karpov Scientific Research Institute of Physical Chemistry).

M.L. Veingerov reported on the physical basis of the design of optical gas analyzers in which the absorption of the infrared and ultraviolet radiations is utilized. He noted that the sensitivity and selectivity of the instruments depended to a great extent on the threshold sensitivity and selectivity of the corresponding radiation receivers, the intensity of the radiation sources, the part of the spectrum in which the absorption lines lie, the length of the absorption cells, and the degree of compression of the gas mixture under test in the cell. The utilization of these factors makes it possible to extend considerably the range of the optical method, raise the sensitivity of the instruments and the accuracy of measurements.

The automatic optico-acoustical gas analyzer developed by the SKB of Analytical Instrument Making and the OKB of Automation was described by E.K. Pechnikov (SKB of Analytical Instrument Making of the Acad. Sci. USSR). CO, $CO_2$ and $CH_4$ gas analyzers (OA-2109, OA-2209 and OA-2309) received a gold medal at the Brussels exhibition.

Representatives of other organizations reported on the development of optical gas analyzers.

Several papers were read on the application of photocolorimetry, photometry and spectrophotometry for analyzing gas mixtures.

S.F. Frish (A.A. Zhdanov Leningrad State University) dealt with the difficulties arising in quantitative spectral analysis of gas mixtures and indicated methods of solving a wide range of problems in spectral analysis.

The physical and chemical basis of the photocolorimetric, photometric and spectrophotometric gas analyzers were described by M.T. Borok.

N.M. Turkel'taub (All-Union Scientific Research Institute of Geological Oil Prospecting) noted the wide possibilities involved in the application of chromatographic analysis for automatic control, especially of multi-component gas media, which is of great importance in modern techniques.

The development of chromatographic gas analyzers was described by A.A. Datskevich (KB of the Means of Automation and Remote Control of the Oil and Gas Industry).

Papers were also read on various designs of mass spectrometers developed by the SKB of Analytical Instrument Making of the Acad. Sci. USSR.

Several papers and reports dealt with auxiliary equipment intended for the selection, preparation and dosing out gas samples.

Unfortunately there were only a few papers or reports presented to the Conference on the experience of using gas analyzers in various branches of industry, and there were no communications on the application of instruments in automatic production.

At the Conference there was organized an Exhibition in which were shown over 50 Soviet and foreign automatic gas analyzers, and advice was given on their use. A selection of Soviet and foreign prospectuses, catalogs, journals and a bibliographical card index were of great interest to the visitors.

The Conference passed a resolution in which the achievement of the gas analyzer production in the USSR was noted, and concrete proposals made on the further development of the scientific research and experimental design work in the sphere of gas analyzer construction. The necessity of increasing the production of gas analyzers was particularly stressed.

## A SCIENTIFIC AND TECHNICAL CONFERENCE ON ELASTIC SENSING ELEMENTS

A.I. Chinarev

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July, 1960

A Scientific and Technical Conference on elastic sensing elements used in measuring instruments and automation was held in Moscow from March 22-25 1960.

The conference was organized by the State Scientific and Technical Committee of the Council of Ministers, USSR and the Scientific Research Institute of Thermal Instruments of the State Committee of the Council of Ministers, USSR, on automation in engineering with the participation of the Scientific and Technical Instrument Making Society together with the administration of the exhibition of the achievements of the USSR national economy.

Some 400 representatives of scientific, design and production organizations of 21 Councils of National Economy took part in the work of the conference.

Thirty-one papers and several reports were read at the Conference.

K.B. Arutyunov described the condition of the scientific research work and development in the sphere of sensing elements and instruments, and proposed a coordinating plan of work, specialization of production, intensification of standardization and the establishment of specialized organizations for the development of the theory, design methods and production technology for the new designs of sensing elements.

L.E. Andreeva informed the conference on the theory of calculating diaphragms and bellows for elasticity and strength, of manometric springs for stiffness and traction effort, and flat oval springs for strength. The paper outlined the tasks and prospects of further work in the theory of computing elastic elements.

S.M. Zasedatelev dealt in his paper with the computing and designing of helical and flat springs used in instruments for measuring force and providing a counter-moment, as well as with flat springs used as ribbon supports and drives and as measuring and tensile springs.

A.I. Chinarev noted in his paper on deformations of the minor axis and the aperture angle of a manometric tube-shaped spring with an elongated oval cross section, that in checking experimentally the basic propositions two aspects of the problem were examined, the power aspect (internal tensions and material) and the kinematic aspect (the shape of the trajectory of separate points of the spring). The paper made certain recommendations

on the design of the transmitting mechanism consisting of a four-link chain which provides a single-valued determination not only of the design but also of the selection of the basis for technological production.

In his report entitled "A technique for an experimental selection of springs for a given mechanism", S.A. Yushchenko supplied graphs which facilitate computations.

S.N. Dranetsyn reported on a computing technique which provides a qualitative evaluation of the effect of parameters on the characteristics of diaphragm-measuring elements.

I.Ya. Retsker described his theoretical and experimental work on the deformation of diaphragms during dynamic loading.

V.P. Chumakov dealt in his report with the problems of designing and producing helical springs.

I.A. Sychev described the research carried cut on four types of welded bellows and a number of welded tube springs, which consisted of two or three shaped strips welded under a pressure of 1 to 100 kg-wt/cm$^2$ along their edges.

A.G. Nagatkin dwelt on the characteristics and means of further improvement of the quality of elastic sensing elements used in the Moscow plant "Manometr".

V.A. Rukhadze described the design, technique of adjusting and setting of instruments for various static loads (from the data of the Scientific Research Institute of Thermal Instruments and the Moscow "Manometr" plant).

V.A. Razin dealt with new methods in the manufacture of seamless bellows.

G.N. Frolov reported on the planning of technological processes in the production of springs and diaphragms for elastic elements (from the data of the Scientific Institute of Automation and Remote Control).

M.M. Kipnis read a paper on the equipment for workshop and laboratory inspection and adjustment of manometers.

In his report V.A. Petrov dealt with the problems of short-pulse, roller welding of thin components and the modernization of machines of the type of MShP and circuit breakers type PISh.

N.L. Kaganov formulated the requirements, conditions, equipment, technology, and supplies for high quality welding.

V.D. Kharitonov provided a comparative analysis of the methods for manufacturing bellows, and proposed requirements for making single and multilayer bellows from alloys of steel, bronze and other metals, and made suggestions for enlarging the types of bellows in use.

K.N. Burtsev dealt with the application of bellows in conjuction with other equipment, with mass produced types, their evaluation and further improvement of their quality.

M.L. Podgoetskii reported on the application of teflon and rubberized cloth diaphragms, the technology of their manufacture, their technical characteristics and methods of determining the defective areas of the diaphragm.

In his report K.I. Manuilov explained the development work in producing, from a thermal bimetallic strip, a spring with reversed wound ends which provides large deformations (7-10 turns) and can be used as a temperature sensing element.

I.G. Lomonosov dealt in his paper with sensing elements made of precision alloys in the oil and gas instruments industry.

A.L. Selyavo investigated in his paper the effect of the annealing (ageing) temperature on the structure and relaxation stability of spring steel.

A.I. Chipizhenko reported on the relation of cyclic strength and elastic hysteresis to the content of beryllium in bronze (from the data obtained in investigating alloys BNT-1.9 and BNT-1.7).

S.I. Berman reported on the means of improving the quality of beryllium bronze used for sensing elements (vacuum smelting).

A.V. Bobylev dealt in his report "A manganese-german silver substitute for beryllium bronze" with a new alloy which possesses a good combination of technological properties and working qualities.

L.D. Kharitonova reported on the research made on a spring alloy for operation at 400°C. This alloy on a nickel and titanium basis provided satisfactory results.

N.G. Chomova reported on alloys for elastic sensing elements with a small elastic modulus temperature coefficient ("elinvar") whose modulus of elasticity remains almost completely constant with varying temperature up to the Curie point.

A.L. Shpitzberg reported on new stainless heatproof steels and alloys for elastic sensing elements and V.N. Sol'ts reported on new nonmagnetic, corrosion-free alloys for elastic sensing elements.

S.A. Poddubnyi stressed the fact that the development of precision instrument making on the basis of a strict linearity of the elastic characteristics of quartz and quartz-glass requires the production not only of special constructional components but also of machines for the manufacture of these elements and their accessories.

The report of N.I. Zhukovskii dealt with the quality of instruments with elastic sensing elements commonly used in industry.*

An exhibition of Soviet-made measuring instruments with new types of elastic sensing elements was organized at the conference.

The conference passed a resolution on the development of computing methods and on improving the design and production technology of elastic sensing elements used in instrument making.

## NEW ELECTRICAL MEASURING INSTRUMENTS

N.N. Skvortsov

Translated from Izmeritel'naya Tekhnika, No. 7, p. 60
July, 1960

A mutual-inductance box, trade mark R538 is used in dc and ac circuits at a frequency up to 2500 cps for all the decades, with the exception of the 10 × 1 mh decade whose upper frequency limit is 1500 cps.

The box consists of four decades: three with stepped switches of 10 × 1 mh, 10 × 0.1 mh and 10 × 0.01 mh and the fourth with a continuously-variable mutual inductance which provides a range of 0.001 to 0.011 mh with calibrations of 0.001 mh.

The basic error of the mutual inductance in this box is expressed in percentage of the nominal value M of the inductance, and must not exceed $\pm (0.3 + 0.1/M)$, where M is the mutual inductance value set on the box and expressed in millihenries.

The box is screened electrically. Its overall dimensions are 280 × 360 × 540 mm, and its weight is 20 kg.

A bridge for measuring dielectric loss and capacitance of capacitors, trade mark R59 is intended for testing capacitors with both their terminals insulated from ground at test voltages of 220 v to 10.5 kv and a frequency of 50 cps with currents of 1 to 200 amp flowing through the tested capacitors. The bridge circuit comprises a reference capacitor R505, a reference capacitor R506 and a vibration galvanometer M501.

The bridge measuring ranges are given in the attached table.

The accuracy of its capacitance measurement is ± 1 % of the measured value.

*See Measurement Techniques No. 7. p. 8 (1960). [See English translation].

| Test voltage, kv | The value of the tested capacitance, μf | |
|---|---|---|
| | min | max |
| 10.5 | 0.32 | 64 |
| 6.3 | 0.50 | 100 |
| 3.15 | 1.0 | 200 |
| 1.05 | 3.2 | 640 |
| 0.5 | 6.4 | 1280 |
| 0.38 | 8 | 1600 |
| 0.22 | 14 | 2800 |

The bridge provides loss angle measuements in the following four ranges: 0 - 1%, 0 - 2%, 0 - 5% and 0 - 10%.

The bridge also provides measurements of capacitance deviations (in percentage of the capacitance read on the bridge) in four ranges: -2% - 0 - +2%, -5% - 0 - +5%, -9% - 0 - +11%, -15% - 0 - +25%.

The value of capacitance $C_X$ of the capacitor under test is determined in microfarads from the following formula:

$$C_X = C_0 r_3 I_r \cdot 10^{-6},$$

where $C_0$ is the capacitance of the reference capacitor, μμf; $r_3$ is the reading of the resistance box obtained in the manual balancing of the bridge, ohms; $I_r$ is the chosen current measuring range, amp.

The bridge null indicator (amplifier and vibration galvanometer) is supplied from the 127 or 220 v, 50 cps mains. The consumption is 50 va.

The bridge equipment is supplied with a safety signalling device and push-buttons for remote switching in and out of the test voltage. The overall dimensions of the bridge are 1250 × 800 × 1000 mm and its weight is 200 kg.

Bridge with trade mark R507 similarly to bridge R59 is intended for measuring dielectric loss of capacitance and capacitors, but has additional devices for automatic registering and recording as functions of time of the dielectric loss and capacitance in technological and research operations.

The R507 bridge has the same electrical characteristics as the R59 bridge. It has the same capacity ranges as the R59 bridge (see Table).

The recording of the loss angle and capacitance are made as functions of time on a tape chart 160 mm wide at a speed of 20 to 720 mm/hr.

The pointer with the pen traverses the whole scale in 8 sec.

The recording devices are supplied from the same source as the galvanometer. Their consumpiton is 300 va. The supply of these instruments must be connected to the same mains as those used for the test voltage.

The bridge equipment is supplied with signalling, safety and remote control devices for switching in and out the test voltage.

Its overall dimensions are 1350 × 900 × 1250 mm, and its weight is 230 kg.

The above instruments are marketed by the Kiev Council of National Economy; their wholesale prices have been approved by the State Planning Committee, USSR and included in catalog No. 922/ts.

# EXHIBITION OF THE NATIONAL FACTORY K. ZEISS

G. Pemzel

Translated from Izmeritel'naya Tekhnika, No. 7, p. 61,
July, 1960

An exhibition of the National Factory K. Zeiss (Jena, GDR) was held at the Polytechnic Museum in Moscow on July,1960. The exhibition occupied over 1000 $m^2$ showing over 100 high-precision measuring instruments of great interest to specialists in this sphere.

The exhibits included various length measuring machines, microscopes, comparators, profile projectors with a magnification of 200 and 600, a projection optimeter, instruments for measuring gears, angles, etc.

Improved and new instruments, some of which were exhibited for the first time at this year's Leipzig Fair, were of special interest.

An instrument for multiple checking of gear wheels is designed on the basis of combined units. By means of auxiliary equipment, which is mounted on the instrument stand, this instrument can be used for combined checking of gears with a double-profile coupling, for determining the deviation of a tooth profile from the involute, for measuring the slope angle of a tooth, circular pitch, the thickness of teeth and the value of the radial run-out. The instrument provides measurements with an amplification of 100, 200 and 500.

An instrument for determining surface quality is based on an optical section method and has several advantages as compared with the previouslyproduced instrument of the same type.

The instrument is supplied with a photographic attachment by means of which it becomes possible to take photographs with a shorter exposture than previously. The image of the surface portion being photographed can be observed at the same time. By means of a drum with cut-slots, it is possible to determine under small magnification the nature of the observed surface in addition to its profile section.

A new screw mounted in the eyepiece makes it possible to use the instrument not only for observation and photography of the surface under test, but also for measuring the value of the irregularity under observation.

The instrument is produced in two models, namely a stationary and a portable one for determining the surface quality of large details and details attached to machines.

Hole gauge for relative measurements of diameters, contrary to instruments for measuring deviations of inside measurements from specified values, is a two-contact device. Owing to this feature it can be mounted by means of a bracket which replaces the set of mounting rings which is required for three-contact instruments of the type mentioned above.

A microscope for measuring hole diameters is intended for a range of 0.05 to 2 mm and thus fills the gap in the set of existing instruments for measuring small internal dimensions. The instrument can be used for measuring hole diameters in jets, watch jewels, throttles, etc. The microscope has a magnification of 75 and is calibrated in 1 $\mu$.

A contactless instrument for measuring thickness by weighing a part of the surface is based on the use of radioactive radiations. According to the utilized radiator the instrument can measure in the process of production the thickness of paper strips, metallic and nonmetallic foils, oilcloths, artificial leather, etc.

It covers a range of 50 to 5000 $g/cm^2$ with an error of 0.1 to 1%.

A more detailed information on various instruments will be published in the following issues of this journal.

# BOOK REVIEWS

B. S. Davydov, The Principles of the Feeler Method For Measuring Surface Roughness.
Standartgiz, Moscow, 1959, 167 pages, 116 illustrations, Edition of 8,000 copies

Reviewed by V. S. Chaman
Translated from Izmeritel'naya Tekhnika, No. 7, pp. 61-62
July, 1960

In recent years interest has been growing in the study of the surface roughness of details made of various materials by different technological methods; moreover the main interest is centered on the geometrical characteristics of the surface (degree of roughness, waviness, etc.), which are determined by means of a diamond feeler scanning the surface.

For the solution of the main research problems various instruments are required which provide information on the geometrical parameters of the surface.

A design engineer who is developing profilometric equipment should without fail acquaint himself with the principles of operation, construction and the electrical circuits of Soviet and foreign instruments of this type; moreover he should have a clear understanding of the physical and mathematical basis of GOST 2789-59 which specifies the roughness measurement of surfaces.

Unfortunately, very little has been written on this subject in our literature; there were no books at all which summarized the experience attained in this sphere or even described Soviet or foreign instruments with a critical evaluation of their properties.

This is why we should welcome the appearance of B.S. Davydov's monograph "The Principles of the Feeler Method for Measuring Surface Roughness" which to a great extent fills the above gap. The book describes the experience of the author's many years of work with different profilometers, with their production and subsequent tests of their accuracy of operation.

Since the feeler methods of checking surfaces are widespread, the author has devoted to them the greatest attention, leaving only a small space for comparing them with penumatic methods of testing which are sometimes used in industry. In chapters I to IV the physical foundations of the feeler method are thoroughly analyzed; the basic criteria adopted in our country and abroad for evaluating the degree of roughness such as $H_{rms}$, $H_{mean}$, $H_M$ etc. are described. These chapters also explain such concepts as the base length and pitch cut-off, new to our designers. These chapters deal with the basic mathematical relations which represent the feeler process of various geometrical profiles by means of a needle with a finite radius on its tip, and investigate the possible measurement errors due to such constructional factors as the radius of curvature of the needle, the transducer reference method, the hardness of the tested surface, the stiffness of the armature suspension spring, etc. It is rather regrettable that these chapters do not contain the brief description and the three basic tables of the new GOST 2789-59 which would have provided very valuable reference material.

Chapters VII and VIII contain a detailed description and critical analysis of the construction and circuits of the early and latest, Soviet and foreign profilometers, thus providing the designer with a means of obtaining correct ideas for selecting the technical characteristics for new instruments.

Chapter X acquaints the reader with the investigations and testing technique adopted for the relative evaluation of the existing profilometer and profilograph designs; accuracy test results are also given in this chapter for certain widely used types of instruments (for instance, KV-7, PCh-2, etc). The chapter provides a good idea of the required and possible accuracy of measuring surface roughness for various instrument designs.

Approximately the same questions are dealt with in chapter XV, which provides an analysis of the existing methods of testing the accuracy of feeler instruments. The detailed description of the theory and practice of certifying electrical feeler profilometers by means of vibrational equipment given in chapter XV is particularly useful. In many instances this method of certification is the only one available to instrument designers and production factories, since to-date we have not yet assimilated mass production of crosshatch roughness standards.

Chapters XII and XIII deal with the important question of comparing the roughness measurment result obtained by various instruments which operate on the basis of different physical principles, i.e., induction, optical or pneumatic.

A designer will find very useful the table given in the appendix in which are listed the basic electrical and mechanical parameters of modern Soviet and foreign instruments for checking surface roughness.

It is regrettable that the monograph deals mainly with the feeler method and hardly touches on the electrical circuits of profilometers. We hope that subsequent publications will fill this gap.

The book includes certain repetitions. Thus instruments for intermittent feeler scanning of surfaces are described twice with almost the same appended drawings. One could consider questionable the advisability of providing such extensive tables as for instance Table 21 which occupies 7 pages, especially since the Table represents a normal recording of a laboratory experiment and its absence would not have decreased the value of the author's conclusions.

In certain cases the quality of the drawings leaves much to be desired, for instance those on pages 38-40 where it was aimed at reproducing photomicrographs of the trace left by a feeler needle on the surface under test, an aim which certainly was not achieved.

All these, on the whole, minor defects do not in any way affect the value of the monograph under review. This is the first book produced in the Soviet Union which contains the theory of the feeler method for investigating micro-configurations required by instrument designers and which describes a large number of existing profilometers and profilographs with their critical evaluation. The chapters summarizing the long experience acquired by the author in precision testing of instruments for measuring surface roughness are of great value.

# COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS

## ALTERATIONS IN THE CURRENT INSTRUCTIONS FOR CHECKING HEIGHT AND SLIDE GAUGES

Translated from Izmeritel'naya Tekhnika, No. 7, pp. 62-63,
July, 1960

On July, 1, 1960 there came into force amendments to instructions 138-57 for checking slide gauges, 139-54 for checking height gauges and 140-54 for checking depth gauges.

In instruction 138-57 (p. 6a) an amendment is made to the backlash of the micrometer screw in the feeding mechanism, in slide gauges newly produced or repaired, not to exceed 1/4 of a turn, and in those now being used not exceeding 1/2 turn.

The requirements for the flatness of the measuring surfaces of jaws used for external measurements in slide gauges in general use were altered (p. 10a). The deviations from flatness of the measuring surfaces of flat jaws for external measurements in slide gauges which are in general use and have a vernier scale of 0.02 and 0.05mm must not exceed 0.002 mm; in slide gauges with a vernier scale of 0.1 mm which are newly produced, repaired or in circulation the deviations from flatness should not exceed 0.006 mm; moreover the gaps between the measuring surfaces must not exceed 0.003 mm for a vernier scale of 0.02 and 0.05 mm, and must not exceed 0.006 mm for a vernier scale of 0.1 mm.

Irregularities of the measuring surface within the limits of 0.2 mm from the edge of the bevels are permitted.

On p. 10b the points at which it is recommended to check the errors of slide gauges have been changed: those with a range of 0-150 mm to 21.2, 51.4, 71.5, 101.6, 126.8 and 150 mm; those with a range of 0-200 mm to 21.2, 51.4, 101.6, 126.8, 150 and 175 mm; those with a range of 0-300 mm to 71.5, 101.6, 126.8, 196.2, 228.4 and 300 mm; those with a range of 0-500 mm to 71.5, 196.2, 276.6, 301.8, 350 and 500 mm.

The block should consist of the least possible number of end gauges (not more than 2).

It is recommended to use a special set of end gauges (set No. 14 GOST 9038-59).

In the instruction 139-54 for checking height gauges the requirements for marking have been changed making the second paragraph of section 5 to read as follows:

"Each height gauge should be marked with: the trade mark of the manufacturing plant, the factory number and designation, the size of the vernier scale and the dimension of height A of the measuring stem".

Similarly to instruction 138-57 the backlash requirements for the micrometer screw of the feeding mechanism have been changed and the recommended points for checking the reading errors of height gauges have also been changed:

For those with an upper measuring limit of 200 mm to 21.2, 51.4, 101.6, 126.8, 150 and 175 mm; for those with an upper measuring limit of 300 mm to 71.5, 101.6, 126.8, 196.2, 228.4 and 300 mm; for those with a measuring limit of 500 mm to 71.5, 196.2, 276.6, 301.8, 350 and 500 mm.

The block should consist of the least possible number of end gauges (not more than 2).

It is recommended to use a special set of end gauges (set No. 14 GOST 9038-59).

In instruction 140-54 for checking depth gauges the requirements for the flatness of the measuring surfaces of the rod and base have been changed making section 5 read as follows:

"Measuring element - the flatness of the measuring surfaces of the rod and the base.

a) Requirements.

The measuring surface of the depth gauge rod, newly produced or repaired, should be flat enough not to be able to see any light with the naked eye when approached to a straight edge.

The measuring surface of the depth gauge base, newly produced or repaired, should be flat enough to provide, when checking by means of a straightedge, a depth gauge with a vernier scale of 0.02 and 0.05 mm, a gap not exceeding 0.005 mm and for a depth gauge with a vernier scale of 0.1 mm a gap not exceeding 0.01 mm.

The measuring surfaces of the rod and base of a depth gauge in general use should be flat enough in order to provide, when checking errors of reading in two position of block gauges, namely at the edges of the base and at the near distance from the rod (fig. 2), errors not exceeding the specified values (p. 10a).

b) Methods of checking.

The flatness is checked by means of a 1st grade straightedge.

The size of the gap is checked by comparing it with "a sample gap" of 0.005 and 0.01 mm.

In order to obtain a "sample gap" four end gauges are lapped to the same glass foundation type PI, grade 2 consisting of a flat plate 60 mm in diameter, in the following manner: the two end ones are 1.01 mm thick and those in between them 1.005 and 1 mm thick respectively.

When the sharp edge of a straightedge is placed over the two end measures, gaps of 5 and 10 $\mu$ are obtained.

The size of the gap is evaluated on sight by comparing it with the "sample gap".

Similarly to the amendments of instructions 138-57 and 139-54, the backlash requirements for the micrometer screw in the feeding mechanism are changed and for the checking of the depth gauge readings the following points are recommended: for those with a range of 0-100 mm to 10.8, 21.2, 30, 51.4, 71.5, and 92.7 mm; for those with a range of 0-150 mm to 21.2, 51.4, 71.5, 101.6, 126.8 and 150 mm; for those with a range of 0-200 mm to 21.2, 51.4, 101.6, 126.8, 150 and 175 mm; for those with a range of 0-250 mm to 21.2, 71.5, 101.6, 126.8, 175 and 228.4 mm; for those with a range of 0-300 mm to 71.5, 101.6, 126.8, 196.2, 228.4 and 300 mm.

The block should be madeup of the least possible number of end gauges (not more than 2).

It is recommended to use the special set of gauges (set No. 14 GOST 9038-59).

Moreover in instruction 132-58 for checking indicating feeler gauges, the requirements regarding the deviation from parallelism of the measuring surfaces have been changed making section 8a of the instruction read as follows:

"The deviation of the measuring surfaces from parallelism in different positions of the measuring rod with respect to height should not exceed 3$\mu$ in all the ranges for feeler gauges TIB and TIK, 5 $\mu$ in TIN-1 and 20 $\mu$ in TR-10A."

## I. NEW SPECIFICATIONS FOR MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE (New Standards)

(Registered May, 1960)
Translated from Izmeritel'naya Tekhnika, No. 7, pp. 63-64,
July, 1960

GOST 577-60. Clock-type indicators with 0.01 mm calibrations. Replacing GOST 577-53.

GOST 8038-60. Ohmmeters. Technical requirements. Replacing GOST 8038-56.

GOST 9444-60. Electrical measuring instruments, torsion suspensions and suspensions.

GOST 9459-60. Instruments for checking bevel wheels. General technical conditions.

## II. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTS AND PASSED FOR USE IN THE USSR.

(Registered May-June, 1960)

Portable voltammeters, trade mark PR-5M of the Ministry of Communications USSR. State register No. 1328-60.

Boxes of nonwirewound resistors, trade mark R-315-P of the Krasnodar Sovnarkhoz. State register No. 1330-60.

Mercury in glass thermometers, trade mark SP-28, SP-29, SP-30, SP-31, SP-32, SP-33 and SP-34 of the Moscow Regional Sovnarkhoz. State register No. 1331-60.

Rod-type, glass toluene thermometers, trade mark SP-1P of the Moscow Regional Sovnarkhoz. State register No. 1332-60.

Spring measuring heads (mikrokators), trade mark O2IGP and O5IGP of the Leningrad Sovnarkhoz. State register No. 1333-60.

Instruments for measuring the configuration of multiblade tools, trade mark 2URI of the Kirov Sovnarkhoz. State register No. 1334-60.

Optical height gauges, trade mark IZV-2 of the Leningrad Sovnarkhoz. State register No. 1335-60.

Weighted piston manometers, trade marks MP-60, MP-600 and MP-2500, grade 0.05 of the Moscow City Sovnarkhoz. State register No. 1336-60.

Mutual-inductance boxes, State register R538 of the Kiev Sovnarkhoz. State register No. 1338-60.

An equipment for measuring losses in electrical steel, trade mark U5011 of the Kiev Sovnarkhoz. State register No. 1339-60.

Phase-sensitive voltmeters, trade mark VF-1 of the Kiev Sovnarkhoz. State register No. 1340-60.

Audio-frequency and ultrasonic signal generators, State register ZG-12M of the Leningrad Sovnarkhoz. State register No. 1341-60.

A bridge for measuring the capacitance and loss angle of capacitors, trade mark R59 of the Kiev Sovnarkhoz. State register No. 1342-60.

A bridge for measuring the capacitance, loss angle of capacitors and recording the test results as functions of time, trade mark R507 of the Kiev Sovnarkhoz. State register No. 1343-60.

Resistance box, trade mark R326 of the Krasnodar Sovnarkhoz. State register No. 1344-60.

Megohmmeters, trade mark M-503 of the Kiev Sovnarkhoz. State register No. 1345-60.

Voltammeters, multirange, portable, trade mark Ts-57 of the Kiev Sovnarkhoz. State register No. 1346-60.

Boxes of microwire resistors, trade mark MSSh-70 of the Moldavian Sovnarkhoz. State register No. 1347-60.

Machines for determining the endurance (fatigue) limit, trade mark MUI-6000 of the Ivanovo Sovnarkhoz. State register No. 1349-60.

Weighted piston reference manometers, trade mark MP-6, grade 0.05 of the Latvian Sovnarkhoz. State register No. 1350-60.

Meters with oval gears for measuring liquids, trade mark SVShS-40 of the Leningrad Sovnarkhoz. State register No. 1351-60.

Radiation telescopes for RAPIR pyrometers, trade mark TERA-50 with measuring ranges: a) 900-1800°C with glass lenses type K-8; b) 400-1400°C with quartz glass lenses of the Kaluga Sovnarkhoz. State register No. 1352-60.

End measuring machines, trade mark IZM-11 of the Leningrad Sovnarkhoz. State register No. 1353-60.

Autocollimators, trade mark PKG-3 of the Novosibirsk Sovnarkhoz. State register No. 1355-60.

Photoelectric luxmeters, trade mark Yu16 of the Leningrad Sovnarkhoz. State register No. 1356-60.

Moving-coil, rack-mounted voltmeters, vibration, shock, and impact proof, trade marks M161 and M171 of the Leningrad Sovnarkhoz. State register No. 1110-60. Combined with moving-coil, rack-mounted voltmeters vibration, shock, and impact proof, trade marks M150, M160, M170, and M180 of the same Sovnarkhoz. State register No. 1110-57.

## III. MEASURES AND MEASURING INSTRUMENTS EXCLUDED FROM THE STATE REGISTER.

(From July 1, 1960)

Portable pointer galvanometer, moving-coil GMP. State register No. 348.

Optical height gauge IZV-1. State register No. 437.

A box of nonwirewound resistors R-315. State register No. 1039-56.

Portable voltammeter PR-5. State register No. 1288-59.